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December 20, 2000

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Ex Parte Filing of Fusion Lighting, Inc. in ET Docket No. 98-42

Dear Ms. Salas:

On behalf of Fusion Lighting, Inc. ("Fusion"), pursuant to Section 1.206 of the Commission's rules, we hereby submit a copy of responses to questions by Sirius Satellite Radio and XM Radio, Inc.

If there are any questions, please call me.

Very truly yours,

Terry G Mahn
Robert J. Ungar
Counsel to Fusion Lighting

Enclosure: Sirius/XM Responses to Questions from Fusion Lighting, Inc.

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No. of Copies rec'd 0
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Attached Certificate of Service

## CERTIFICATE OF SERVICE

I hereby certify that on this 20th day of December, 2000, I caused copies of the foregoing **Ex Parte Filing of Sirius Satellite Radio Inc. in ET Docket No. 98-42** to be mailed via first class postage prepaid mail to the following:

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fusionLighting

December 13, 2000

## FUSION LIGHTING'S RESPONSE TO DARS QUESTIONS

1) Provide information on the nature of the radiated emissions, including spectrum graphs, to include in ISM and out of band emissions in the DARS band of 2320-2345 GHz. In addition, include descriptions of measurement techniques utilized to obtain the data.

   - Inband and out of band data was presented to XM and Sirius Satellite Radio at the FCC meeting on October 16, 2000.

   - Joint testing of lamps was conducted at PC Test on November 3, 2000. Full report was provided to XM Radio and Sirius Satellite Radio.

2) Provide information on the radiation pattern to be expected from the installed lights. What is the direction that the lights are generally pointed?

   - In general, RF emissions will be strongest in the direction that the light beam is focussed. The reflector provides directionality to both the light and RF signal.

   - Joint testing of the RF beam patterns was conducted at PC Test on November 3, 2000. A full report was provided to XM Radio and Sirius Satellite Radio.

   - Lamps can be and are pointed in all directions. Outdoor lamps are primarily focussed downward. Major exceptions are wall washers used to illuminate buildings and signage at night, which use an up-light configuration, and area lighting, which uses light pipes where the lamp is mounted horizontally.

3) Provide information on the expected deployment, for example, of lighting a parking lot: how many and how far apart would the lights be deployed? The number of devices likely to enter the RF environment? The density of their deployment? The proximity to DARS receivers?

   - Fusion's electrodeless lamps can be made in a wide range of power levels and lumen packages. We are specifically targeting replacement of 250, 400 and 1000 watt sodium and metal halide lamps. The sulfur lamp provides both better nighttime vision and a 30 to 50% energy savings. We expect the location and density of the Fusion lamp to be nearly identical to the pattern of lamps now found on streets, highways and parking lots.



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The annual US market for outdoor lighting systems addressable by the sulfur lamp is 8,500 million units valued at over 1B dollars. The global market is four to five times this number.

4) For indoor deployment, please provide results of any testing on the attenuation measured through walls.

   - Fusion has no data on attenuation through walls or other obstacles.

5) Provide description of the excitation methodology for Fusion Lighting RF lighting devices. Please include information concerning main excitation frequency of the argon – sulfur mixture, excitation levels required, description of the actual energy states of the mixture which are being used in this application.

   - Fusion Lighting patents which teach the basics of the sulfur lamp are provided.

     : Lamp including sulfur – Patent No. 5,404,076

     :Apparatus for exciting an electrodeless lamp with an increasing electric field intensity – Patent No. 5,594,303

     :One piece microwave container screen for electrodeless lamps – Patent No. 5,811,936

     :Lamp with light reflection back into bulb – Patent No. 5,773,918

     :Compact Microwave Lamps Having a Tuning Block and a Dielectric Located in a Lamp Cavity – Patent No. 6,031,333.

6) Provide following information on the physical design: description of the magnetron and cavity used for excitation; description of the filtering method used in the design for the exciter and cavity; detailed information on suppression efforts of current filtering and shielding methods and alternative designs considered for increased filter and shielding.

   - The basic design of the microwave circuit are shown in the attached drawing.

   - The magnetron used is a standard home cooker device such as the Matsushita model 2M244. These devices are manufactured in quantities of tens of millions per year. These magnetrons are the only cost effective high power microwave power source.

- Fusion's standard lamp design employs a double RF shield. The wire mesh screen which surrounds the bulb defines a resonant cavity and contains most of the microwave energy (see Fusion Lighting Patent Number 5,811,936). This screen is designed to minimize RF leakage while maximizing the amount of light that can pass through the screen. The screen is plated to improve electrical conductivity, thus reducing emissions and to improve reflectivity to aid the light's escape from the bulb cavity. Increasing the thickness or density of the wire mesh will reduce light output, making the lamp less efficient and increasing the thermal load on the system.

- To ensure that Fusion's lamps are in full compliance with FCC requirements throughout the life of the lamp, a second RF shield is incorporated into each lamp. Each lamp is equipped with a metallic reflector and an ITO coated cover glass. This combination acts as a second RF containment cavity around the bulb.

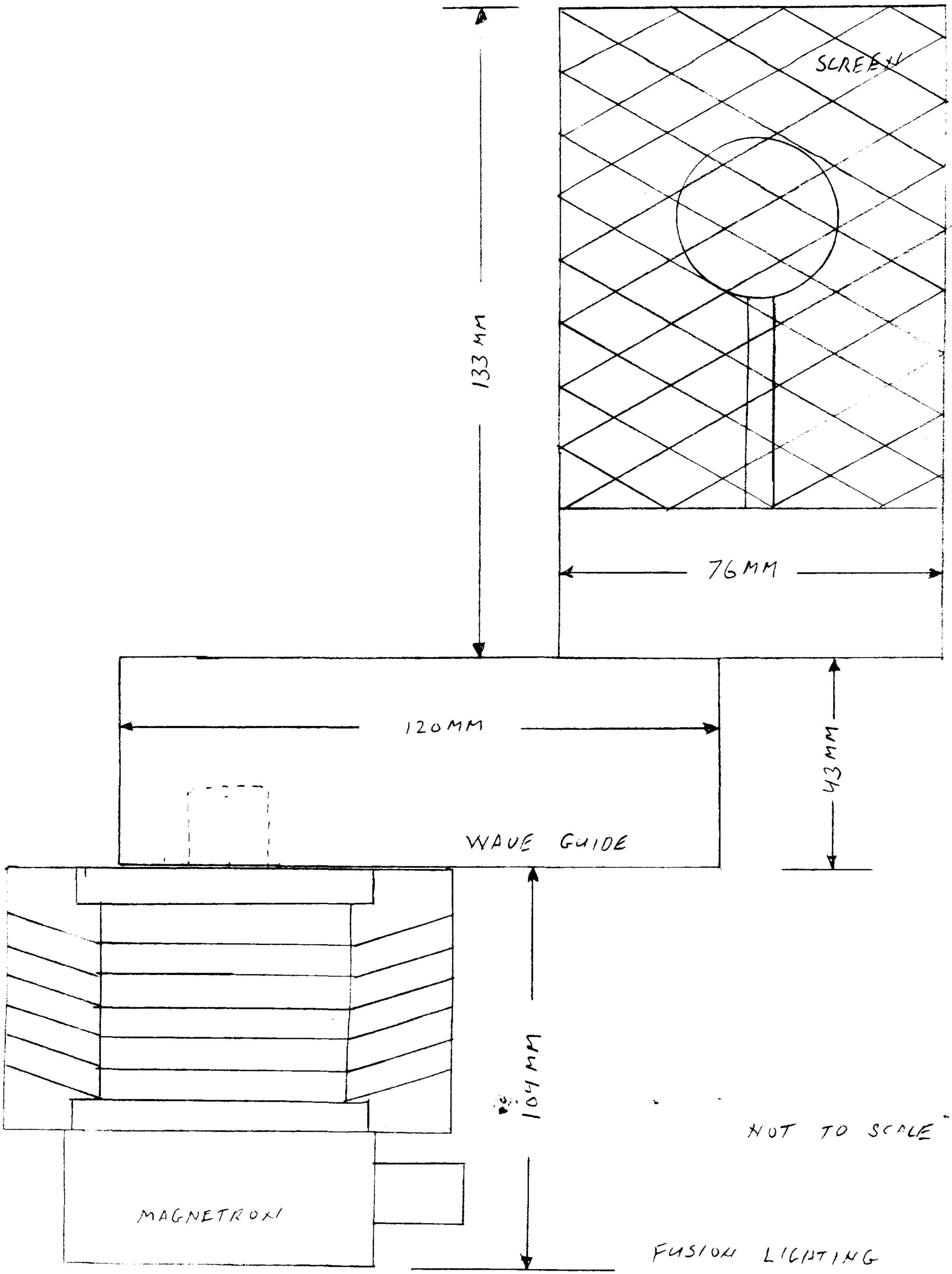
- Fusion has made extensive studies of the feasibility of adding additional RF screens and shield around the lamp. A summary of these studies was provided to XM and Sirius Radio. The conclusion: increasing RF shielding significantly reduces the light output of the lamp, rendering the lamp non-competitive.

  At the suggestion of the DARS group, Fusion Lighting studied the possibility of employing notch filter specifically tuned to protect the 2.320-2.345 GHz band.

- Both multi-pole band-pass and absorption matched band-stop filter designs were investigated. All potential solutions were found to be expensive, complex and physically large. A band-stop filter would more than double the size of a lamp and would not achieve more than 10 to 15 dB of attenuation. The band-pass filter grows the lamp in a similar manner. While capable of achieving more than 15 dB of attenuation, it will cause a RF phase shift that will prevent the lamp from starting properly and possibly destroy the magnetron.

7) Provide information on the nature and manner of any redesign to the present product to ensure meeting the 18 μV/meter at 3 meter level for out of band emissions in the DARS band.

   - Fusion knows of no economically feasible technical solution that would ensure compliance with an 18 μV/meter limit at 3 meters. All potential solutions we have considered both increase the cost of the lamp and substantially reduce lamp efficacy. The adoption of any limit significantly lower than the current FCC limit would effectively destroy Fusion Lighting's business.


SCREEN
133 MM
76 MM
120 MM
43 MM
WAVE GUIDE
104 MM
MAGNETRON
NOT TO SCALE
FUSION LIGHTING

L 81 1200 3

US005404076A

# United States Patent [19]

Dolan et al.

[11] Patent Number: 5,404,076

[45] Date of Patent: Apr. 4, 1995

[54] LAMP INCLUDING SULFUR

[75] Inventors: James T. Dolan, Frederick; Michael G. Ury, Bethesda; Charles H. Wood, Rockville, all of Md.

[73] Assignee: Fusion Systems Corporation, Rockville, Md.

[21] Appl. No.: 71,027

[22] Filed: Jun. 3, 1993

Related U.S. Application Data

[63] Continuation of Ser. No. 604,487, Oct. 25, 1990, abandoned.

[51] Int. Cl.[5] ........................ H01J 17/20; H01J 61/12; H01J 61/18

[52] U.S. Cl. .................................... 313/572; 313/637; 313/638; 313/643; 315/248

[58] Field of Search ............... 313/572, 550, 637, 638, 313/643; 315/248

[56] References Cited

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 4,427,922 | 1/1984 | Proud et al. | 315/248 |
| 4,476,413 | 10/1984 | Gough et al. | 313/550 |
| 4,937,503 | 6/1990 | Sigai et al. | 315/248 |
| 4,945,290 | 7/1990 | Eliasson et al. | 313/637 X |

FOREIGN PATENT DOCUMENTS

55-10755 1/1980 Japan .

OTHER PUBLICATIONS

Patent Abstracts of Japan, vol. 4, No. 40 (E-004), Mar. 28, 1980 relating to JP-A-55 010 755 (Ushio Inc), Jan. 25, 1980.

Childs et al., "Some Characteristics of Low Pressure, Sulfur, Microwave-Excited, Electrodeless Discharge Lamps", Applied Spectroscopy, vol. 30, No. 5, pp. 507-509, 1976, Baltimore US.

Bentley et al., "Preparation of Electrodeless Discharge Lamps for Elements Forming Gaseous Covalent Hydrides", Analytical Chemistry, vol. 49, No. 4, Apr. 1977, pp. 551-554, Columbus US.

*Primary Examiner*—Sandra L. O'Shea

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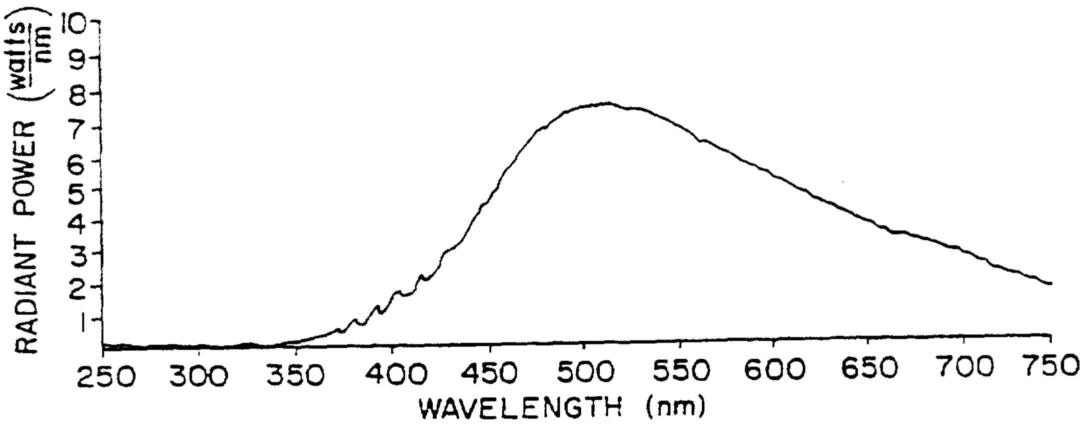
[57] ABSTRACT

A high power lamp which utilizes a lamp fill containing sulfur or selenium, or compounds of these substances. An electrodeless lamp utilizing such a fill at a pressure at least as high as 1 atmosphere is excited at a power density in excess of 50 watts/cc. An arc lamp utilizing the fill at a pressure at least as high as 1 atmosphere is excited at a power density of at least 60 watts/cm.

45 Claims, 2 Drawing Sheets



# LAMP INCLUDING SULFUR

This application is a continuation of Ser. No. 07/604,487, filed Oct. 25, 1990, now abandoned.

The present invention is directed to a new, high power lamp.

High power lamps are used for many illumination applications. The incandescent and fluorescent lamps, so familiar in homes and offices, do not provide enough illumination for many commercial and industrial applications. In fact, the lamp which has gained acceptance and which is typically used for high power illumination is known as the high intensity discharge (HID) lamp. This lamp is simple in structure, and generally consists of a glass envelope which contains two electrodes and a fill which vaporizes and becomes a gas when the lamp is operated.

The fill in the HID lamp usually contains mercury as its primary component. However, this is undesirable because mercury is a highly toxic and environmentally hazardous substance. Thus, if a HID lamp should break, dangerous mercury fumes would be emitted, and after the useful life of the lamp is over, there is no easy way to safely dispose of the mercury containing envelope. The widespread use of mercury containing lamps has been recognized as a serious environmental problem.

It is a feature of the present invention that instead of mercury, a substance which contains sulfur or selenium is used in the lamp fill.

In accordance with a first aspect of the present invention, elemental sulfur or selenium, or compounds of these elements, is included in a lamp fill. The fill is present at a pressure of at least about 1 atmosphere, and is excited with electromagnetic energy at a relatively high power density. Each of the above-mentioned substances has a low vapor pressure at room temperature, yet a high vapor pressure at typical lamp operating temperatures. The preferred embodiment of the invention utilizes a sulfur fill.

In accordance with a further aspect of the invention, elemental sulfur or selenium, or compounds of these elements is used as the primary radiating component of a lamp fill. The term "primary radiating component" as used herein means that radiating component of the fill which is present at at least about the same or greater partial pressure than the other radiating fill components during operation of the lamp, or that radiating component which is the sole radiating component in the fill. The resultant lamp of the invention avoids the environmental hazards which are associated with mercury based lamps. Additionally the performance indicators for the lamp are relatively good.

There are many ways to measure how good a lamp is, and amongst those skilled in the lamp art the use of various standardized performance indicators has arisen. These include the luminous efficacy of the lamp, its rated life, lumen maintenance, chromaticity, and color rendering index (CRI). Finally, the stability of the color of the light which is emitted by the lamp is important, as this may change over time. The closer these accepted indicators are to ideal, the better the performance of the lamp.

As described above, the lamp of the invention avoids the environmental hazards which are associated with mercury based lamps, and additionally the resultant performance indicators for the lamp are relatively good.

In a first embodiment of the invention, a high power lamp of the electrodeless type is provided, which is powered by microwave energy. High power electrodeless lamps are well known in the art, but have generally if not always contained a mercury fill. Additionally, the lamps have primarily been used for their output in the ultraviolet rather than the visible portion of the spectrum. In the electrodeless lamp of the invention, a high pressure fill at least as high as 1 atmosphere is utilized, which includes sulfur or selenium, or a compound thereof. Additionally, the fill may include a gas such as argon or xenon. The high pressure fill is excited at power densities in excess of 50 watts/cc, and preferably in excess of 100 watts/cc. Furthermore, various additives such as metal halides, arsenic boron, etc., may be included in the fill to emphasize different areas of the spectrum.

The efficiency of production of useful radiation of the lamp of the invention is relatively high. In fact, it is significantly higher than for the conventional electrodeless lamp which utilizes a mercury fill. The ability to provide such a lamp is an unexpected result, as the fill substances used in accordance with the invention have a higher heat conductivity than mercury so that it would be expected that more heat would be lost to the bulb walls, and that the efficiency of production of useful radiation would be lower than with the mercury lamp.

In a further embodiment of the invention, an arc lamp which has electrodes is provided. This is similar to the previously described mercury containing HID lamp, but instead of mercury, the fill includes a sulfur or selenium containing substance. As in the case of the electrodeless lamp, the addition of additives to the fill may be used to emphasize particular spectral regions. For example, sodium might be used to increase the orange and red radiation from the lamp.

In the prior art, low pressure, low power lamps are known which have been used in the laboratory for the scientific study of the spectrum (atomic spectroscopy). It is conventional in such laboratory work to use each of the elements of the periodic table, including the fill substances proposed herein, as the fill for electrodeless and arc lamps, so as to generate the atomic and molecular spectra of such elements. However, such lamps would be wholly unsuitable as high power visible, illumination sources. In fact, when the spectra generated with the lamps of the present invention were compared with the atomic or molecular spectrum generated by the low power, low pressure atomic spectroscopy lamps using the same fill, it was noted that for at least some implementations of the present invention, the ultraviolet part of the spectrum which appeared prominently in the spectrum of the atomic spectroscopy source was substantially and unexpectedly suppressed in the lamp of the invention, thus resulting in higher luminous efficacy, and in the generation of less harmful ultraviolet radiation.

It is thus an advantage of the present invention that a new, high power lamp is provided, which does not need to contain mercury.

It is a further advantage of the invention that a new, high power lamp bulb is provided which does not need to contain mercury.

It is a further advantage of the invention that a new, high power lamp is provided which has relatively good performance indicators.

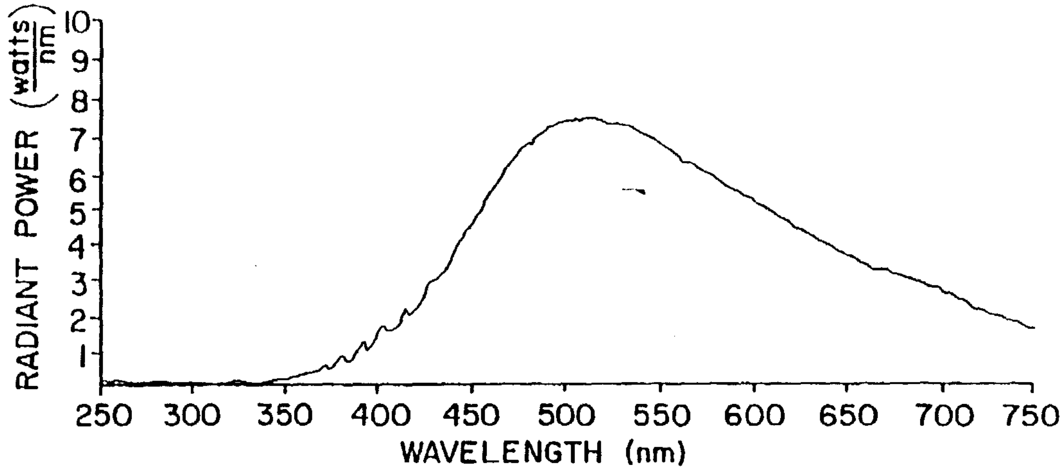

RADIANT POWER (watts/nm)
10
9
8
7
6
5
4
3
2
1
250 300 350 400 450 500 550 600 650 700 750
WAVELENGTH (nm)

FIG. 3

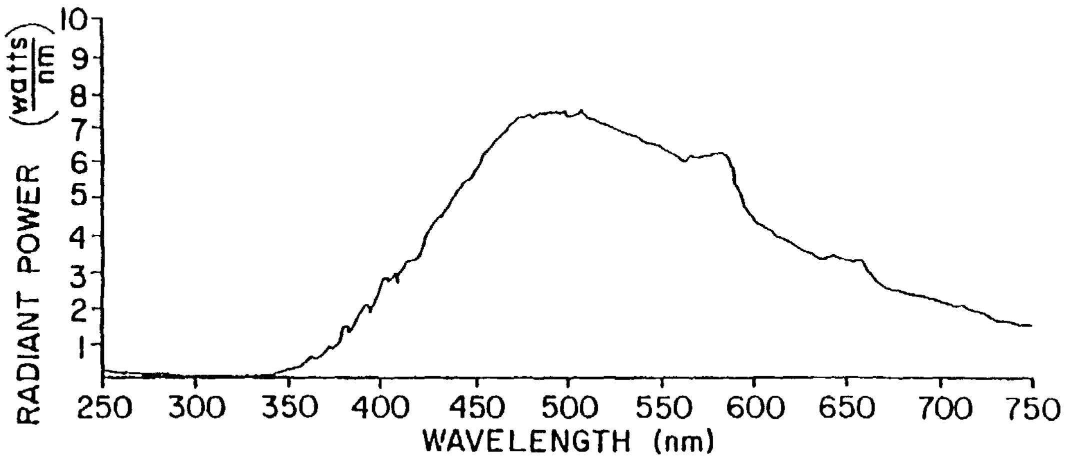

RADIANT POWER (watts/nm)
10
9
8
7
6
5
4
3
2
1
250 300 350 400 450 500 550 600 650 700 750
WAVELENGTH (nm)

FIG. 4

radiation principally within the visible range. A unique feature of the lamp of the present invention may be that it is a high luminous efficacy lamp which emits principally molecular radiation.

A still further advantage of the electrodeless lamp embodiment of the invention is that it is a compact, high power, visible radiator. Thus, the diameter of the bulb is typically only 2-3 cm, while outputs of about 140 lumens/watt or greater are possible.

A further embodiment of the invention is shown in FIG. 2. This is an arc lamp 20 which is comprised of quartz envelope 22 having electrodes 24 and 26, and containing fill 28. To excite the fill, an A.C. voltage is impressed across the electrodes, whereupon an arc discharge occurs therebetween.

In accordance with the invention, the fill in envelope 22 includes a sulfur containing substance or a selenium containing substance. In accordance with an aspect of the invention, this fill substance is the primary radiating component in the fill. The substance may be elemental sulfur or selenium or compounds of these elements. Additionally, a small amount of an additional gas to aid in starting is provided, which can be an inert gas, such as argon or xenon.

As in the case of the electrodeless lamp, the fill is present at a high pressure of at least about 1 atmosphere and preferably in the range of about 2-20 atmospheres. This pressure is controlled mainly by the sulfur or selenium containing substance thereof, the partial pressure of which is at least about 1 atmosphere. Additionally, an electrical voltage is applied across the electrodes such that a power density of at least 60 watts/cm, exists. The electrodes 22 and 24 are made of or plated with a special material, such as platinum, to prevent chemical reactions with the fill gas, which may lead to electrode deterioration. Electrode materials other than platinum, which do not react with the fill gas, may be used.

In one implementation of the invention, the fill of either an electrodeless or arc lamp is arranged so that sulfur or selenium containing substance is the sole radiating component in the bulb fill. In such an implementation, the sulfur or selenium containing substance may be the only substance in the fill except for a small amount of a gas to aid starting, e.g., argon or xenon.

As a specific example of the invention, an electrodeless quartz bulb of spherical shape having an internal diameter of 2.84 cm was filled with 0.062 mg-moles/cc of sulfur, and 60 torr of argon. When the bulb was placed in a microwave cavity and excited with microwave energy at a power density of about 280 watts/cc, visible light was emitted having a spectrum as shown in FIG. 3. The luminous efficiency of the lamp was about 140 lumens/watt. Additionally, it is noted from the spectrum that there is minimal UV radiation beneath 350 nm. This feature helps to increase the luminous efficacy of the lamp and also enhances the safety of the lamp, as UV radiation is a health hazard. It is also noted from FIG. 3 that the spectral plot is smooth and does not contain sharp peaks, which results from the fact that the lamp is principally a molecular as opposed to an atomic radiator.

As a further specific example of the invention, an electrodeless bulb of spherical shape having an internal diameter of 2.84 cm was filled with 0.053 mg-moles/cc of sulfur, 0.008 mg-moles/cc of cadmium and 0.003 mg-moles/cc of cadmium iodide. When the lamp was excited with microwave energy at a power density of 280 watts/cc, visible light was emitted having a spectrum as shown in FIG. 4. The luminous efficacy of the lamp was about 134 lumens/watt. Additionally, it is noted that the spectrum has a shoulder at 580 nm, which is caused by the CdS and another shoulder at 650 nm, which is caused by the $CdI_2$.

A new, high power lamp which can be made without mercury has thus been disclosed. While the lamp has been described primarily as a high power visible source of illumination, certain implementations may find use in other areas of the spectrum, e.g., the U.V. Additionally, while the invention has been illustrated in accordance with specific embodiments, it should be understood that variations falling within the spirit of the invention will occur to those skilled in the art, and the invention is to be limited only by the claims which are appended hereto and equivalents.

We claim:

1. An electrodeless lamp comprising,
   a) an envelope of light transmissive material for containing a discharge,
   b) a fill in said envelope which includes elemental sulfur, the fill having a pressure of at least about 1 atmosphere at operating temperature, and
   c) excitation means for coupling electromagnetic energy to said fill at a power density of at least 50 watts/cc for exciting said discharge.

2. The electrodeless lamp of claim 1 wherein it is the sulfur which primarily controls said fill pressure.

3. The electrodeless lamp of claim 1 wherein said fill includes a gas for aiding in starting the discharge.

4. The electrodeless lamp of claim 1 wherein said excitation means couples electromagnetic energy to said fill at a power density of at least about 100 watts/cc.

5. The electrodeless lamp of claim 1 wherein said excitation means includes means for generating microwave energy which is coupled to said fill.

6. The electrodeless lamp of claim 3 wherein said fill further includes a metal halide.

7. The electrodeless lamp of claim 3 wherein said fill further includes a substance selected from the group of arsenic, boron, and bismuth.

8. The electrodeless lamp of claim 1 wherein said fill in said envelope which includes elemental sulfur further includes CdS.

9. An electrodeless lamp comprising,
   a) an envelope which contains a fill in which elemental sulfur is the primary radiating component, the fill having a pressure of at least about 1 atmosphere at operating temperature, and
   b) excitation means for coupling electromagnetic energy to said envelope at a power density of at least about 50 watts/cc to excite said fill.

10. The electrodeless lamp of claim 9 wherein the fill further includes a gas for aiding in starting the discharge.

11. The electrodeless lamp of claim 9 wherein said excitation means couples electromagnetic energy to said fill at a power density of at least about 100 watts/cc.

12. An electrodeless lamp comprising,
   a) an envelope of light transmissive material for containing a discharge,
   b) a fill in said envelope which includes elemental selenium, the fill having a pressure of at least about 1 atmosphere at operating temperature, and

The invention will be better appreciated by referring to the accompanying drawings, wherein:

FIG. 1 shows a first embodiment of the invention.

FIG. 2 shows a further embodiment of the invention.

FIG. 3 is a spectral plot for an electrodeless lamp utilizing a sulfur bulb fill.

FIG. 4 is a spectral plot for an electrodeless lamp utilizing a bulb fill containing sulfur and cadmium iodide.

Referring to FIG. 1, a first embodiment of the invention is depicted. Lamp 2 is an electrodeless lamp which is powered by microwave energy. Bulb 3, which contains a high pressure fill, and is made of quartz or other suitable material, is supported in a microwave cavity, which is comprised of conductive housing 4 and mesh 5. Magnetron 6 generates microwave energy, which is fed by waveguide 7, to coupling slot 8 of the microwave cavity.

This excites the bulb fill to a plasma state, whereupon light is emitted by the fill, which is transmitted out of the cavity through mesh 5. The mesh is metallic, and is constructed so that it is substantially opaque to microwave energy, while being substantially transparent to the light which is emitted by bulb 3. The bulb is rotated by rotator 9, and the bulb envelope is cooled by gas which is fed in to plenum 10 and out through nozzles 11.

In accordance with an aspect of the invention, the fill in bulb 4 includes elemental sulfur or selenium, or a compound of one of these elements. In accordance with a further aspect of the invention, this substance is present as the primary radiating component of the bulb fill. It is further desirable to use a fill component which aids in starting the discharge, and for example, a small amount of an inert gas, such as argon or xenon may be used for this purpose.

The lamp which is shown in FIG. 1 may be characterized as a high power, high pressure lamp. Thus, the fill in bulb 3 is present in amounts such that the fill pressure is at least one atmosphere or above at operating temperature, and is preferably 2 to 20 atmospheres. Additionally, the amplitude of the microwave energy which is fed to the cavity is such that the power density of the energy which is coupled to the fill is at least 50 watts/cc, and preferably in the range of 100 to 400 watts/cc. It should be understood that the absolute amount of the primary fill component in solid form which is used in the bulb may vary depending on which substance is used, e.g., sulfur or selenium, but the amount always will be such to produce the desired pressure range at operating temperature, i.e., the temperature of the bulb during normal operation at a power density of 50 watts/cc or greater. The fill pressure is mainly controlled by the primary fill component, which typically has a substantially higher partial pressure than that of the inert gas when the lamp is operational. Further, the illumination provided by the lamp shown in FIG. 1 may be augmented in various regions of the spectrum by including certain additives in the fill. By way of non-limitative examples such additives may include metal halides, arsenic, boron, carbon and bismuth. Examples of some of the many metal halides which can be used are $CdI_2$, HgCl, and $InI_3$. Also, in certain implementations, the addition of some mercury may improve operation by reducing the restrike time of the lamp.

As noted above, in addition to using sulfur, selenium, and phosphorous in elemental form, compounds of these elements may be used. For example, $CS_2$, InS, $AS_2S_3$, $SeO_2$, and $SeCl_4$, as well as other compounds of sulfur and selenium, may be used. The term "a sulfur containing substance" as used herein, includes both elemental sulfur and sulfur compounds, while the same is true for the corresponding terms as applied to selenium. It should be appreciated that the primary radiating component of the fill may be comprised of a combination of a sulfur containing substance or substances and selenium containing substance, rather than only one of these substances. Additionally, the primary radiating component may be comprised of a mixture of the elemental form and a compound(s) of a particular substance, e.g., sulfur.

While microwave energy is the preferred mode of excitation of lamp 2, it would also be possible to provide excitation with electromagnetic energy in the radio frequency range. Since this typically would involve wrapping an excitation coil around the bulb, which would obscure some of the emitted light, the microwave mode of excitation is preferred. However, the term "electromagnetic energy", as used herein, refers to both microwave and r.f. modes. Also, while the microwave cavity which is illustrated in FIG. 1 does not include a reflector, a reflecting cavity could also be used.

As mentioned above it appears that the performance indicators of the lamp of the invention are relatively good. In this regard it is noted that electrodeless lamps, which have heretofore been used mainly to produce ultraviolet as opposed to visible light, tend to maintain their lumen output at a high level for a longer period of time than arc lamps, and this may be an advantageous property of the electrodeless lamp embodiment of the present invention.

An additional advantage of the present lamp is that the primary radiating fill component may be a single element. Thus, the most common type of HID lamp presently used for high power illumination applications is the metal halide type HID lamp, wherein mercury is combined with the halide of another metal or metals in order to achieve the desired spectral output. A commonly used combination is Hg+ScI+NaI. The partial pressure of the additive metals is determined by the amount of metal halide in the lamp and by the temperature of the coldest spot on the lamp. The result is that variations in these parameters due to manufacturing tolerances or lamp aging will cause changes in the partial pressure of the additive, which in turn causes changes in the amount of output and in the spectral distribution of the output. On the other hand, since the present lamp may have only a single radiating fill component, or in accordance with an aspect of the invention have a fill which consists essentially of a sulfur containing substance or a selenium containing substance, and an inert gas, any effect caused by the partial pressures of different fill components changing at different rates will not occur.

A further advantage of the lamp of the invention is that it may emit principally molecular as opposed to atomic radiation which results in a smoother spectrum without peaks or abrupt transitions and possibly a better color rendering index. In this regard it is noted that non-metals have found little application as fill materials in the prior art, and one reason for this is that the primary atomic spectral lines of the non-metals do not lie in the visible region. However, the present invention, at least in certain implementations relies on molecular radiation as the dominant source, and is able to provide a fill enclosed in said envelope including a sulfur containing substance from which elemental sulfur molecules in gaseous form can be obtained upon excitation, which is present in an amount such that when said fill is excited by sufficient power in operation, the excited fill emits visible radiation from the elemental sulfur molecules with substantially all of the radiation from the elemental sulfur molecules being emitted at wavelengths longer than about 350 nm.

31. An electrodeless lamp, comprising,

a light transmissive envelope for containing a discharge,

a fill in said envelope which includes a sulfur containing substance from which elemental sulfur in gaseous form is obtained upon excitation, which is present in an amount such that when said fill is excited with sufficient power, the excited fill emits visible radiation from the elemental sulfur, with substantially all of the radiation from the elemental sulfur being emitted at wavelengths longer than about 350 nm, and

means for exciting said fill with sufficient power to cause said elemental sulfur to emit said visible radiation and said radiation, substantially all of which is emitted at wavelengths longer than about 350 nm.

32. The electrodeless lamp of claim 31 wherein said means for exciting applies microwave or r.f. power to the fill.

33. The electrodeless lamp of claim 31 wherein said elemental sulfur is the primary radiating component.

34. The electrodeless lamp of claim 31 wherein said elemental sulfur emits more radiation than any other substance in the excited fill.

35. An electrodeless lamp comprising,

a) an envelope of light transmissive material for containing a discharge,

b) a fill present in said envelope which includes a sulfur containing substance from which elemental sulfur in gaseous form is obtained upon excitation, the fill being present in an unexcited lamp in an amount such that a pressure of at least about one atmosphere is created and the elemental sulfur emits principally molecular radiation in the visible region when the fill is excited with sufficient power, and

c) excitation means for coupling power to said fill which is sufficient to cause said elemental sulfur to emit said principally molecular radiation in the visible region.

36. The electrodeless lamp of claim 35 wherein said elemental sulfur is the primary radiating component.

37. The electrodeless lamp of claim 35 wherein the elemental sulfur emits more radiation then any other substance in the excited fill.

38. The electrodeless lamp of claim 35 wherein the excitation means comprises means for coupling power to said fill, at a power density of at least about 50 watts/cc.

39. An electrodeless lamp comprising,

a) an envelope of light transmissive material for containing a discharge,

b) a fill present in said envelope which includes a sulfur containing substance from which elemental sulfur in gaseous form is obtained upon excitation, which is present in an amount such that when said fill is excited with sufficient microwave or r.f. power, the excited fill emits visible radiation from the elemental sulfur, with substantially all of the radiation from the elemental sulfur being emitted at wavelengths longer than about 350 nm and with the elemental sulfur emitting more radiation than any other substance in the fill, and

c) excitation means for coupling microwave or r.f. power to said fill which is sufficient to cause said elemental sulfur to emit said visible radiation and said radiation, substantially all of which is emitted at wavelengths longer than about 350 nm.

40. An arc lamp, comprising,

a light transmissive envelope which includes electrodes,

a fill enclosed in said envelope including a sulfur containing substance from which elemental sulfur molecules in gaseous form can be obtained upon excitation, which is present in an amount such that when said fill is excited by sufficient power in operation, the excited fill emits visible radiation from the elemental sulfur with substantially all of the radiation from the elemental sulfur being emitted at wavelengths longer than 350 nm, and

means for exciting said fill by the application of sufficient power to said electrodes to obtain said elemental sulfur molecules in gaseous form which emit said visible radiation and said radiation, substantially all of which is emitted at wavelengths longer than about 350 nm.

41. The apparatus of claim 40 wherein said elemental sulfur emits more radiation than any other substance in the fill.

42. An electrodeless lamp comprising,

a) an envelope of light transmissive material for containing a discharge,

b) a fill present in said envelope which includes a selenium containing substance from which elemental selenium in gaseous form is obtained upon excitation, the fill being present in an unexcited lamp in an amount such that a pressure of at least about one atmosphere is created and the elemental selenium emits molecular radiation principally in the visible region when the fill is excited with sufficient microwave or r.f. power, and

c) excitation means for coupling microwave or r.f. power to said fill which is sufficient to cause said elemental selenium to emit said molecular radiation principally in the visible region.

43. The electrodeless lamp of claim 42 wherein said elemental selenium is the primary radiating component.

44. The electrodeless lamp of claim 42 wherein the elemental selenium emits more radiation then any other substance in the excited fill.

45. The electrodeless lamp of claim 42 wherein the excitation means comprises means for coupling power to said fill, at a power density of at least about 50 watts/cc.

* * * * *

c) excitation means for coupling electromagnetic energy to said fill at a power density of at least 50 watts/cc for exciting said discharge.

13. The electrodeless lamp of claim 12 wherein said excitation means couples electromagnetic energy to said fill at a power density of at least about 100 watts/cc.

14. The electrodeless lamp of claim 13 wherein said fill further includes a gas for aiding in starting the discharge.

15. The electrodeless lamp of claim 14 further including a fill additive for emphasizing a particular region of the spectrum.

16. An electrodeless lamp comprising,

a) an envelope of light transmissive material for containing a discharge,

b) a fill in said envelope in which elemental selenium is the primary radiating component, the fill having a pressure of at least about 1 atmosphere at operating temperature, and

c) excitation means for coupling electromagnetic energy to said fill at a power density of at least 50 watts/cc for exciting said discharge.

17. An arc lamp, comprising,

a) an envelope of light transmissive material which includes electrodes,

b) a fill in said envelope consisting essentially of selenium and a gas for aiding in starting the discharge, the fill having a pressure of at least about 1 atmosphere, and

c) excitation means for applying a voltage to said electrodes for coupling energy to said fill at a power density of at least 60 watts/cm.

18. An arc lamp comprising,

a) an envelope including electrodes which contains a fill in which elemental selenium is the primary radiating substance, the fill having a pressure of at least about 1 atmosphere at operating temperature, and

b) excitation means for applying a voltage to said electrodes for coupling energy to said fill at a power density of at least 60 watts/cm.

19. An electrodeless lamp comprising,

a) an envelope of light transmissive material for containing a discharge;

b) a fill in said envelope consisting essentially of elemental sulfur and an inert gas, the fill having a pressure of at least about one atmosphere at operating temperature; and

c) excitation means for coupling microwave energy to said fill at a power density of at least 50 watts/cc for exciting said discharge to emit radiation.

20. An arc lamp, comprising,

a) an envelope of light transmissive material which includes electrodes,

b) a fill in said envelope consisting essentially of elemental sulfur and a gas for aiding in starting the discharge, the fill having a pressure of at least about one atmosphere at operating temperature, and

c) excitation means for applying a voltage to said electrodes for coupling energy to said fill at a power density of at least 60 watts/cm.

21. An arc lamp, comprising,

a) an envelope of light transmissive material which includes electrodes,

b) a fill in said envelope in which elemental sulfur is the primary radiating component, the fill having a pressure of at least about 1 atmosphere at operating temperature, and

c) excitation means for applying a voltage to said electrodes for coupling energy to said fill at a power density of at least 60 watts/cm.

22. An electrodeless lamp bulb comprised of a light transmitting envelope which contains a fill which includes elemental sulfur and an inert gas in such amounts to produce a fill pressure of at least one atmosphere at operating temperature, with the partial pressure of the sulfur being substantially greater than the partial pressure of the inert gas.

23. An electrodeless lamp bulb comprised of a light transmitting envelope which contains a fill in which elemental sulfur is the primary radiating component, the fill also including an inert gas, the elemental sulfur and inert gas being present in amounts to produce a fill pressure of at least 1 atmosphere at operating temperature.

24. An electrodeless lamp bulb comprised of a light transmitting envelope which contains a fill which includes elemental selenium and an inert gas in such amounts to produce a fill pressure of at least 1 atmosphere at operating temperature, with the partial pressure of the selenium being substantially greater than the partial pressure of the inert gas.

25. An arc lamp bulb comprised of a light transmitting envelope which includes electrodes and which contains a fill in which elemental sulfur is the primary radiating component, the fill further including an inert gas, and having said elemental sulfur and said inert gas present in amounts so as to produce a fill pressure of at least 1 atmosphere at operating temperature.

26. An arc lamp bulb comprised of a light transmitting envelope which includes electrodes and which contains a fill in which elemental selenium is the primary radiating component, the fill also including an inert gas, said elemental selenium and said inert gas being present in amounts so that a fill pressure of at least one atmosphere is produced at operating temperature, the fill pressure being primarily controlled by the selenium.

27. An arc lamp bulb comprised of a light transmitting envelope which includes electrodes and which contains a fill consisting essentially of elemental selenium and an inert gas, said elemental selenium and said inert gas being present in amounts to produce a fill pressure of at least one atmosphere at operating temperature.

28. A lamp bulb for providing visible radiation when in operation, comprising,

a light transmissive envelope, and

a fill in said envelope including elemental sulfur in gaseous form which is obtainable when said fill is excited by sufficient power in operation, in an amount such that the excited fill emits visible radiation from the elemental sulfur with substantially all of the radiation from the elemental sulfur being emitted at wavelengths longer than about 350 nm.

29. The lamp bulb of claim 28 in combination with,

means for exciting said fill with sufficient power to obtain said elemental sulfur in gaseous form during operation which emits said visible radiation and said radiation, substantially all of which is emitted at wavelengths longer than about 350 nm.

30. A lamp bulb for providing visible radiation, comprising,

a light transmissive envelope, and

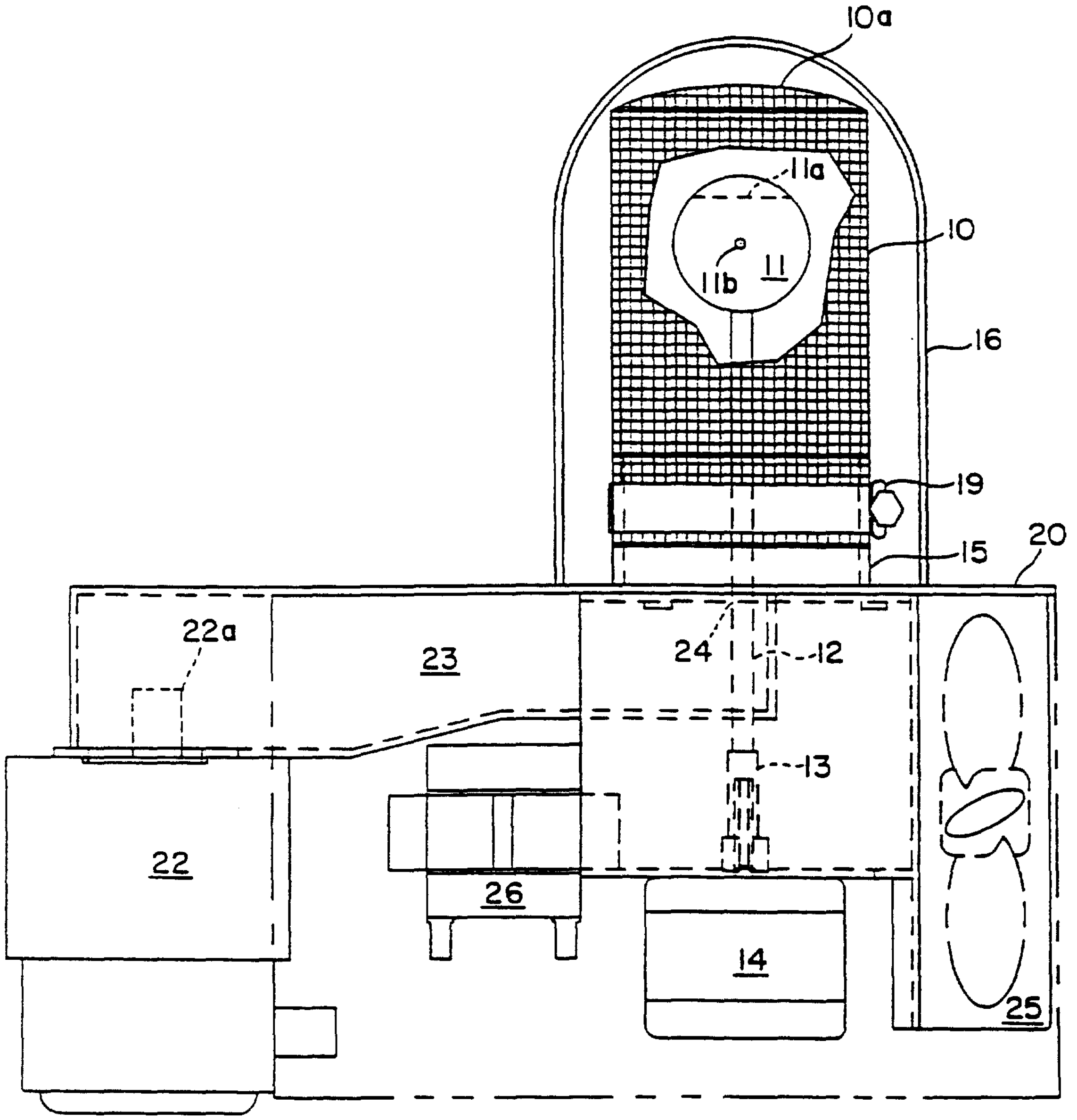



FIG. 1

US005594303A

# United States Patent [19]

Simpson et al.

[11] Patent Number: 5,594,303

[45] Date of Patent: Jan. 14, 1997

[54] APPARATUS FOR EXCITING AN ELECTRODELESS LAMP WITH AN INCREASING ELECTRIC FIELD INTENSITY

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[73] Assignee: Fusion Lighting, Inc., Rockville, Md.

[21] Appl. No.: 402,065

[22] Filed: Mar. 9, 1995

[51] Int. Cl.[6] ........ H01J 65/04

[52] U.S. Cl. ........ 315/39; 315/248; 315/344

[58] Field of Search ........ 315/39, 248, 344

[56] References Cited

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,942,058 | 3/1976 | Haugsjaa et al. | 315/39 X |
| 4,749,915 | 6/1988 | Lynch et al. | 315/39 X |
| 4,887,008 | 12/1989 | Wood | 315/39 |
| 4,887,192 | 12/1989 | Simpson et al. | 315/39 X |
| 4,954,755 | 9/1990 | Lynch et al. | 315/248 |
| 4,975,625 | 12/1990 | Lynch et al. | 315/39 X |
| 5,227,698 | 7/1993 | Simpson et al. | 315/298 |
| 5,361,274 | 11/1994 | Simpson et al. | 315/39 X |

FOREIGN PATENT DOCUMENTS

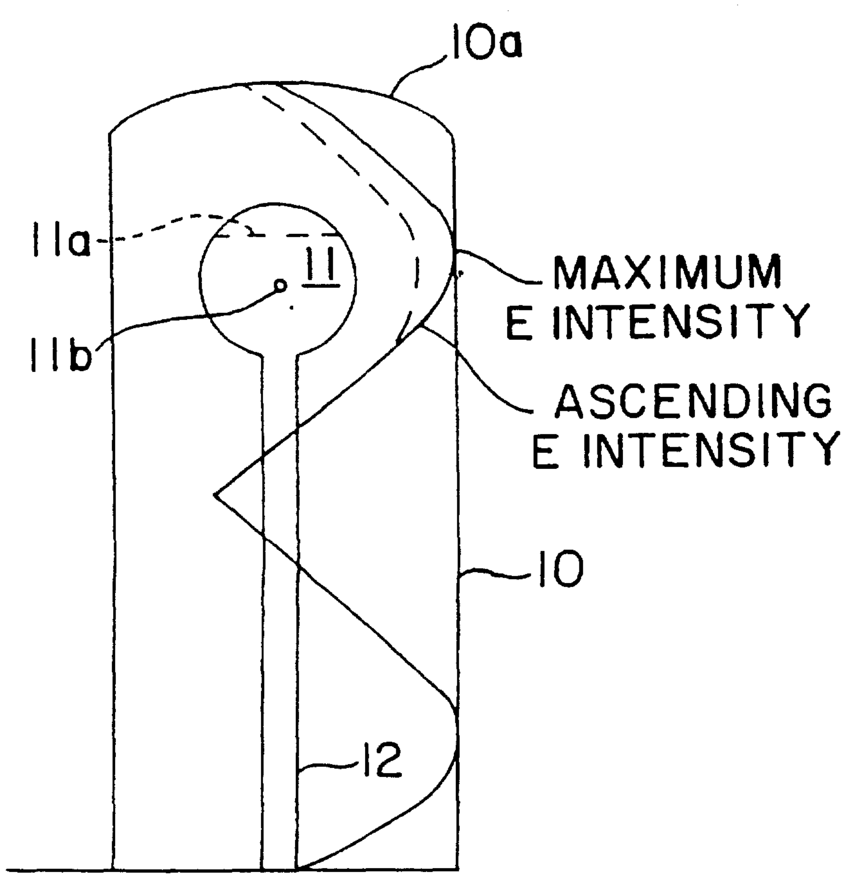
| | | | |
|---|---|---|---|
| 126250 | 10/1981 | Japan | 315/39 |

Primary Examiner—Benny T. Lee
Attorney, Agent, or Firm—Pollock, Vande Sande & Priddy

[57] ABSTRACT

Apparatus for efficiently exciting an electrodeless lamp to produce visible light. A source of microwave energy is coupled to a cylindrical cavity which encloses an electrodeless lamp. The cylindrical cavity includes a sidewall and end wall which is made from a metallic mesh which passes light produced from the electrodeless lamp. The electric field intensity within the cylindrical cavity is increased in the region above the lamp center. The increased electric field intensity produces a more uniform temperature across the bulb service, increasing the rate of plasma heating of gas molecules in the lamp.

10 Claims, 5 Drawing Sheets

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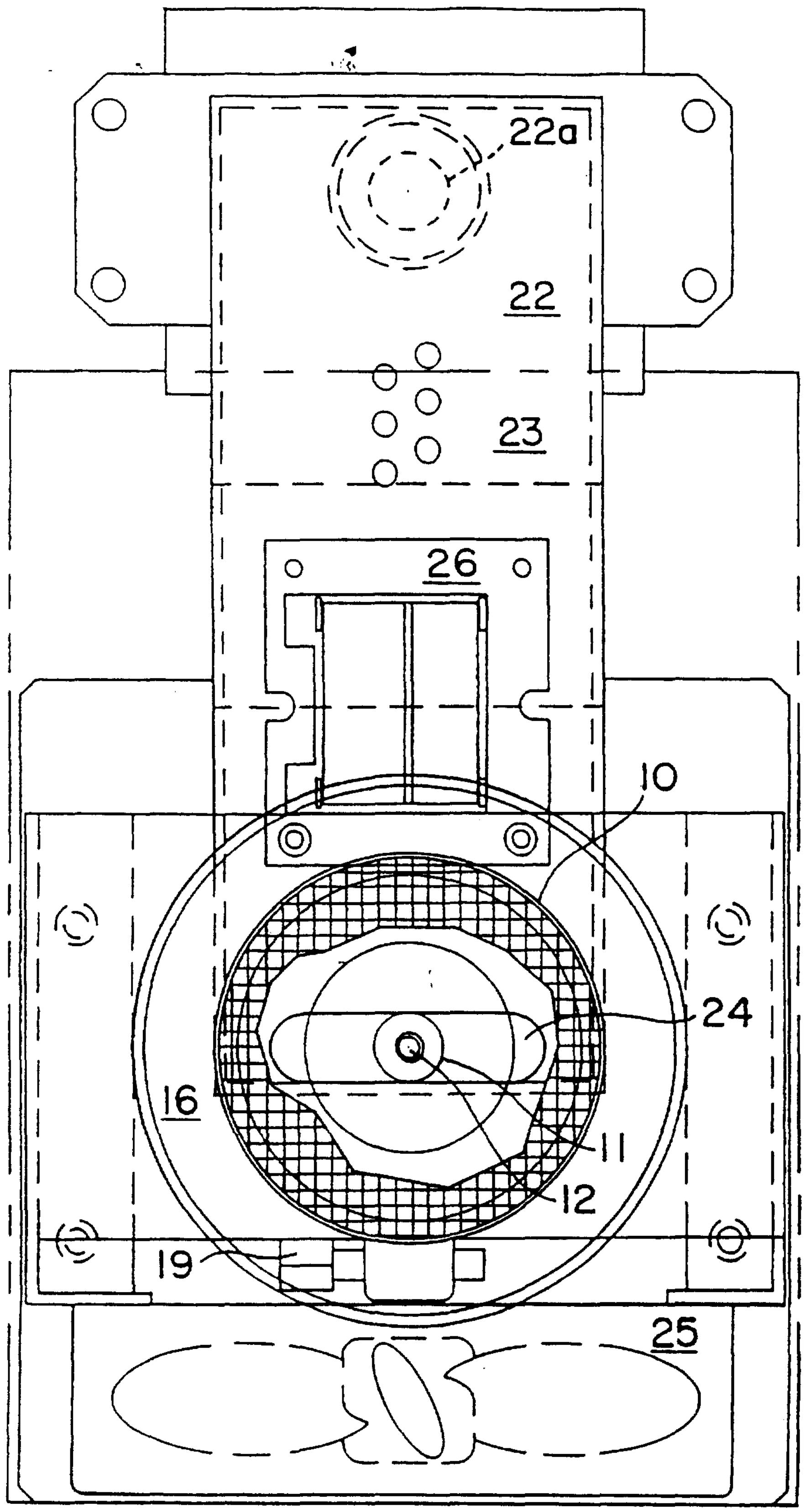



FIG. 3

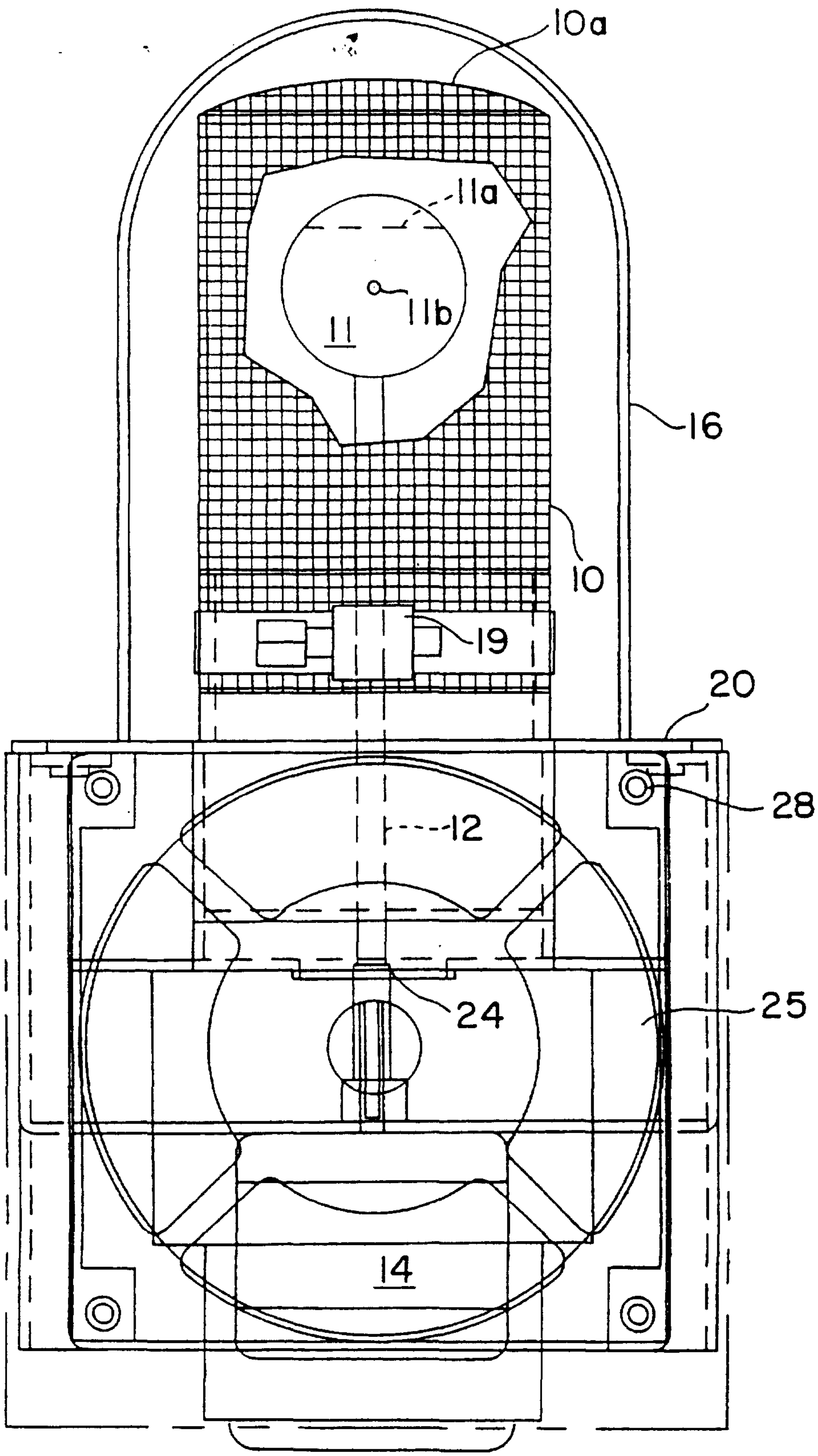
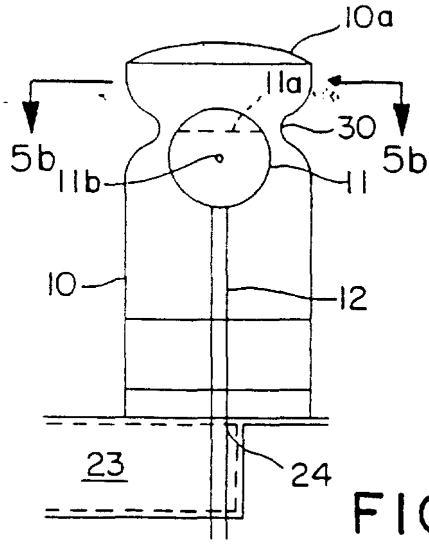



FIG. 2



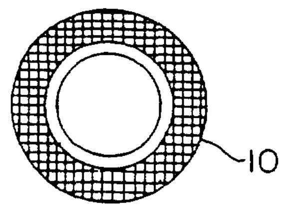
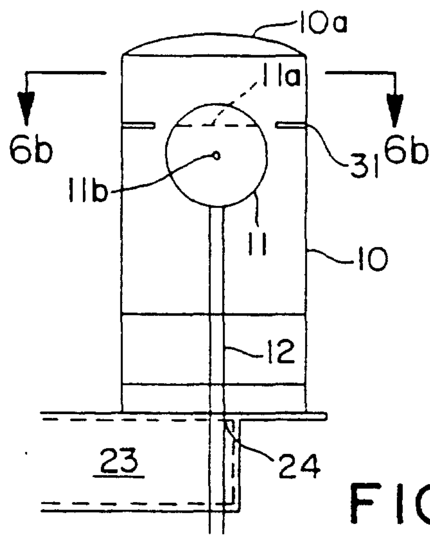




FIG. 5b

FIG. 5a



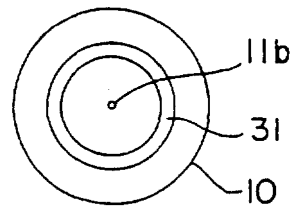
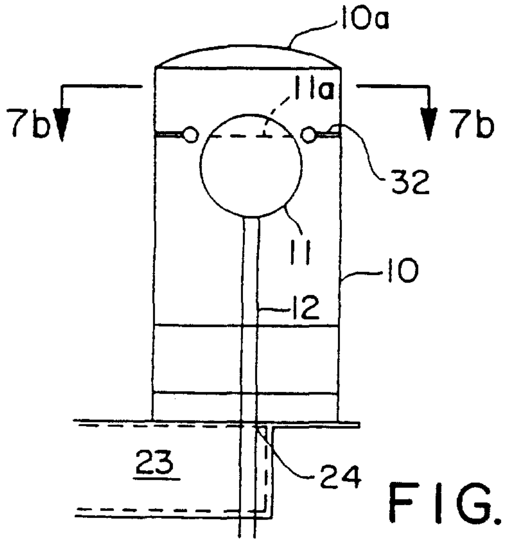




FIG. 6b

FIG. 6a



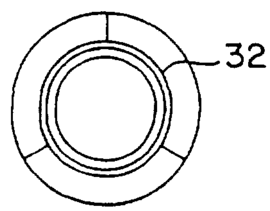




FIG. 7b

FIG. 7a

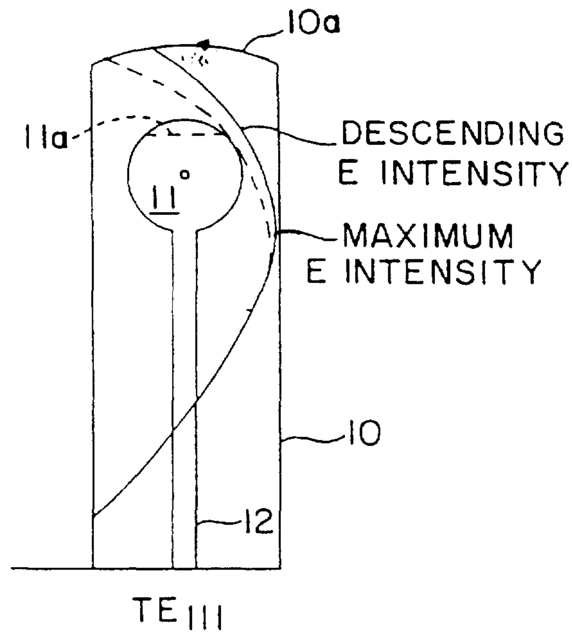



FIG. 4A
PRIOR ART

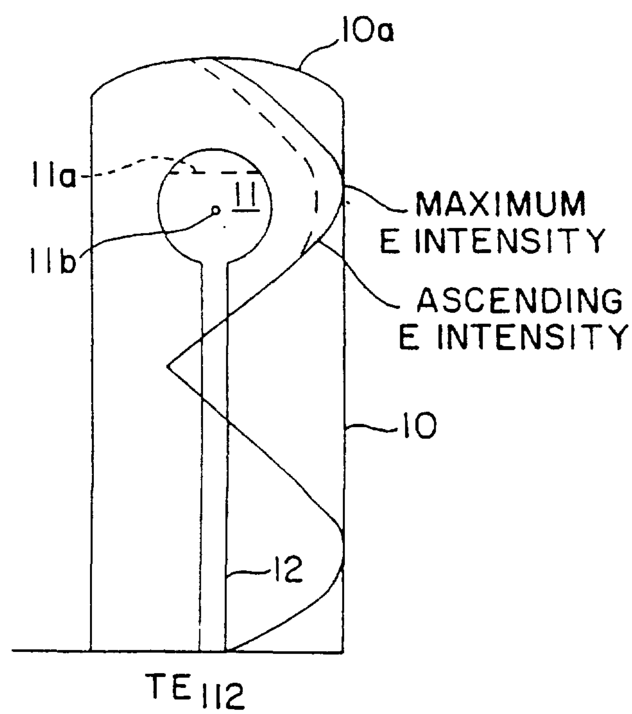



FIG. 4B

11, and provides circumferential temperature uniformity to the lamp 11, thus prolonging its life.

The electrodeless lamp 11 is shown inside cylindrical cavity 10 which may include an apertured surface to emit light from the lamp 11 while confining the electromagnetic radiation within the cylindrical cavity. The cylindrical cavity 10 has sidewalls and an end wall **10a** which may be made from a metallic mesh or screen which emits light.

The apertured portion of the cavity **10** is clamped via a clamp **19** to cylindrical flange **15** bolted to the surface of the waveguide **23**, forming the top of housing **20**. A transparent protection dome **16** is placed over the cavity **10**.

The lamp **11** includes a top portion **11a** above the lamp center **11b**, which is subject to a local temperature differential with respect to the remaining portion of the lamp **11**. When a $TE_{111}$ mode is supported within the cavity **10**, the electric field in the region of lamp portion **11a** is decreasing in intensity, and microwave illumination of the lamp, particularly in the region **11a**, is non-uniform, resulting in uneven heating of the lamp **11**.

The sulfur or selenium molecules within the lamp **11** are unevenly heated and may produce a dark, light impermeable region in a portion **11a** of lamp **11** above the center of the lamp **11b**. This reduces the amount of light which is generated through portion **11a**, decreasing total light output and making light output non-uniform over the surface of lamp **11**. FIGS. 2 and 3 depict different views of the lamp **11** described in FIG. 1, where features identical to those in FIG. 1 are designated by the same reference numerals and are not further described herein.

FIG. 4A illustrates the field distribution within the cylindrical cavity **10** which was used in the prior art which identifies the source of unequal heating of the lamp **11** supported on shaft **12**. The solid line represents the sinusoidal electric field distribution of a $TE_{111}$ propagation mode supported within cylindrical cavity **10** with end **10a** in the absence of a lamp. The portion of the $TE_{111}$ electric field distribution adjacent region **11a**, is descending in electric field (E) strength with the maximum intensity below the lamp center **11(b)**. Less energy is thus absorbed by the electrodeless lamp in region **11a**, resulting in a lower temperature than in the region opposite the ascending portion of the electric field distribution.

In the presence of the lamp, the broken line illustrates how the electric field strength rapidly reduces in the region **11a**, resulting in a lower temperature, producing a light-absorbing gas in sulfur- and selenium-filled lamps. Light production in region **11a** suffers due to the light absorbing gas.

In accordance with a preferred embodiment of the invention, the cavity **10** is a cylindrical cavity having end **10a** supporting a $TE_{112}$ propagation mode. The cylindrical cavity **10** may be configured in length and dimensions in accordance with a conventional mode chart for right circular cylindrical cavities as described in the text "Introduction to Microwave Theory and Measurements" to support a $TE_{112}$ propagation mode. The $TE_{112}$ mode, as shown in FIG. 4B, provides for an electric field distribution along the axis of the cylindrical cavity **10** with end **10a** which has two sinusoidal peaks associated with it. The second sinusoidal peak is located such that an ascending increasing intensity of the electric field (E) is adjacent the region **11a** of the electrodeless lamp **11** with shaft **12**, increasing the electric field strength in the region **11a** above the lamp center **11(b)**. The increased electric field intensity in this region increases the temperature of region **11a**, reducing the amount of light absorbing gas which forms at the top of the electrodeless lamp **11a**.



The length of the cylindrical cavity **10** is selected so that the lamp **11** may be supported on shaft **12** far enough away from the slot **24** to avoid coupling of the fringe field associated with slot **24** with the lamp **11** as shown for example in FIG 1.

The increased electric field at the top of the lamp provides a more uniform discharge and prevents the formation of sludge or higher order molecules which degrade the lamp's light generation efficiency. The rate of energy absorption, particularly in a sulfur plasma within the lamp, is increased near the top of the lamp, increasing plasma heating of the gas molecules.

In the $TE_{111}$ mode, positioning the bulb further down the cavity where the electric field intensity is rising would result in better heating of the top of the lamp. However, this would reduce the optical access to the lamp, and would promote near field interaction with the fringe fields produced at the boundary between the cylindrical cavity **10** and the slot **24** of the waveguide **24**.

Other techniques for locally increasing the electric field intensity near the top of the lamp **11** are shown in FIGS. 5A, 5B, 6A, 6B, 7A and 7B. These techniques do not require the $TE_{112}$ resonant mode. These alternative techniques are illustrated using reference numerals which are common to the embodiment of FIGS. 1–3 and 4B.

FIGS. 5A and 5B show a narrowing of the cavity **10** in the region **11a** (see FIG. 5A) of the lamp to create a restriction **30** (see FIG. 5A) for increasing the electric field intensity in region **11a**.

FIGS. 6A and 6B illustrate an iris **31** which is located within the cylindrical cavity **10** at a location opposite region **11a** (see FIG. 6A) for increasing the electric field intensity in the region above the lamp center **11b**.

FIGS. 7A and 7B illustrate the use of a suspended torroidal metallic ring **32** which increases the field intensity in the region **11a** of the lamp **11** (see FIG. 7A).

Each of the foregoing embodiments achieves the objective of maintaining the lamp **11** sufficiently distant from the slot **24** to avoid coupling with the fringe field produced from the coupling slot **24**. Further, the height of the lamp **11** from the housing **20** permits full optical access to the lamp.

Thus, there has been described with respect to several embodiments, a technique for efficiently illuminating an electrodeless bulb which avoids local temperature differentials in the bulb, thus increasing light output. Those skilled in the art will recognize yet other embodiments of the invention as described more fully by the claims which follow.

What is claimed is:

1. An apparatus for exciting an electrodeless lamp with microwave energy comprising:

a source of microwave energy;

a cylindrical cavity coupled to said source of microwave energy, having a plurality of light emitting apertures, said cylindrical cavity supporting microwave energy coupled from said source having an electric field which varies sinusoidally along an axis of said cylindrical cavity; and

an electrodeless lamp supported for rotation on a motor driven shaft in said cylindrical cavity along the axis of said cavity at a location which is distant from a location which produces fringe fields from coupling said microwave source to said cylindrical cavity, and located so that a portion of said electrodeless lamp above a center of said electrodeless lamp is illuminated by a portion of

# APPARATUS FOR EXCITING AN ELECTRODELESS LAMP WITH AN INCREASING ELECTRIC FIELD INTENSITY

The present invention relates to the field of apparatus for exciting electrodeless lamps. Specifically, an apparatus for uniformly radiating an electrodeless lamp with improved illumination efficiency is described.

Electrodeless lamps have been employed in the past to generate high intensity radiant light in excess of 100,000 lumens. These devices are used in industrial lighting in both indoor and outdoor applications. Among the advantages of electrodeless lamps is an enhanced life of between 10,000 and 20,000 hours. Further, greater power efficiency is obtained than with other conventional light sources.

Electrodeless lamps may be designed to emit mostly infrared light, ultraviolet light or visible light. In applications wherein visible light is needed, electrodeless lamps are sulfur or selenium filled to produce mostly visible light. Other lamps of other materials, such as mercury, can be used to generate ultraviolet and infrared light in industrial applications where these wavelengths of light are needed.

Sulfur and selenium filled lamps have a light output which can be affected by local temperatures within the lamp. These gas-filled lamps show dark bands, particularly along the top thereof, when the lamp surface is not uniformly heated. Cooler portions of the lamp can produce discoloration which absorbs light disproportionately from the remaining portion of the lamp surface. Temperature differentials within the bulb are very often the result of an uneven field distribution of the microwave energy which is supported by a resonant cavity containing the lamp. The uneven field distribution produces an uneven discharge which in turn produces "sludge", a dark gas containing higher order sulfur molecules which degrade the lamp's performance. Therefore, in order to avoid the consequences of local temperature differentials within the lamp, the microwave illumination of the bulb should produce a uniform temperature across the surface of the lamp.

Other circumstances which impact on the efficiency of illumination of the electrodeless lamp include interaction of the fringe field produced between the microwave energy source and the cavity with the electrodeless lamp. The lamp can distort the coupling fields between cavity and microwave energy source, introducing an impedance mismatch and consequent power loss, lowering the system's efficiency.

## SUMMARY OF THE INVENTION

It is an object of this invention to efficiently illuminate an electrodeless lamp with microwave energy.

It is a more specific object of this invention to provide for a microwave illumination field which heats an electrodeless lamp uniformly over its entire surface.

It is yet another object of this invention to increase the amount of visible light generated by a microwave illuminated electrodeless lamp.

These and other objects of the invention are provided for by a microwave illumination system which improves the electromagnetic field distribution about an electrodeless lamp so that portions of the lamp which run cooler are exposed to an ascending or increasing electric field intensity. The electrodeless lamp is supported for rotation in a cylindrical cavity about the cavity axis. The cylindrical cavity has an apertured surface which emits light generated by the electrodeless lamp when excited by microwave energy.



Control over the electromagnetic field distribution is accomplished in a preferred embodiment of the invention by configuring the cylindrical cavity to support the $TE_{112}$ resonant mode. In this mode, an ascending portion of the electric field can be positioned adjacent the portion of an electrodeless lamp which would normally remain cooler, increasing the electric field intensity, thus raising the temperature of the normally cooler portion of the lamp.

In other embodiments of the invention, a local discontinuity is introduced in the cylindrical cavity wall, increasing the electric field intensity on the portion of the electrodeless lamp which normally runs cooler than the remaining portion of the lamp.

## DESCRIPTION OF THE FIGURES

FIG. 1 is a plan view of an apparatus for generating light from an electrodeless bulb.

FIG. 2 is an end view of the apparatus of FIG. 1.

FIG. 3 is a top view of the apparatus of FIG. 1.

FIG. 4A illustrates the electric field distribution within a cylindrical cavity when excited with a TE111 mode as is known in the prior art.

FIG. 4B illustrates the improved field distribution from a TE112 mode.

FIG. 5A is a section view of a cylindrical cavity having a restriction along its length for increasing the electric field near the top of an electrodeless lamp.

FIG. 5B is a top view of FIG. 5A.

FIG. 6A illustrates an iris supported in the cylindrical cavity for increasing the electric field near the top of the electrodeless lamp.

FIG. 6B is a top view of FIG. 6A.

FIG. 7A illustrates a torroidal ring within the cylindrical cavity for increasing the electric field near the top of the electrodeless lamp.

FIG. 7B is a section view of FIG. 7A.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1, 2 and 3, there is shown respectively, plan, end and top views of an apparatus for generating light from an electrodeless lamp **11**. The electrodeless lamp **11**, in the preferred embodiment of the invention, contains either sulfur or selenium, which, when excited with microwave energy, generates primarily visible light. The apparatus of FIG. 1 includes a housing **20** which is open along the top, and which encloses a filament transformer **26** for providing filament current to a magnetron **22**, a motor **14** for rotating an electrodeless lamp **11**, and a cooling fan **25** for providing cooling air to the magnetron **22**.

The magnetron **22** is a commercially available magnetron operating at approximately 2.45 GHz. The magnetron **22** has an antenna **22*a*** coupled to a waveguide section **23** which enters the housing **20** and closes the top of housing **20**. Waveguide section **23** couples the microwave energy from magnetron **22** to a longitudinal slot **24** on the top wall of the waveguide. Microwave energy coupled through slot **24** propagates along the longitudinal axis of cylindrical cavity **10** towards end **10*a***.

The electrodeless lamp **11** is supported on a shaft **12** which is coupled via coupling **13** to the motor **14**. As is known in the electrodeless lamp art, rotation of the lamp **11** at several hundred RPM creates a uniform plasma in lamp said electric field which is increasing in intensity along the length of said cavity, whereby said electrodeless lamp has a surface area which is heated at a substantially constant temperature across the surface area thereof.

2. The apparatus for exciting an electrodeless lamp according to claim 1, wherein said cylindrical cavity includes a toroidal ring along the length of said cylindrical cavity for increasing said electric field intensity.

3. The apparatus for exciting an electrodeless lamp according to claim 1, wherein said cylindrical cavity has a length and diameter which support a $TE_{112}$ mode of operation.

4. The apparatus for exciting an electrodeless lamp according to claim 1, wherein said cylindrical cavity includes an iris along said length for creating said increasing electric field intensity.

5. An apparatus for producing high intensity visible light comprising:

a housing supporting at one end thereof a magnetron and at an opposite end thereof a cooling fan which supplies forced air to said magnetron, and further including a motor with a driven shaft extending through said housing;

an electrodeless lamp supported on said driven shaft; and, a light emitting cylindrical cavity supported on said housing, said cylindrical cavity enclosing said electrodeless lamp, and coupled through said housing to said magnetron, whereby microwave energy generated by said magnetron is coupled to said cavity, said cavity supporting an electric field which increases in intensity along a longitudinal axis of said cylindrical cavity in a region above a center of said lamp and adjacent an end of said electrodeless lamp, thereby decreasing local temperature variations in said lamp.

6. The apparatus of claim 5, wherein said cavity supports said microwave energy having an $TE_{112}$ mode.

7. The apparatus of claim 5, wherein said cavity includes means located above the center of said electrodeless lamp for increasing the electric field intensity in the region above said lamp center.

8. The apparatus of claim 7, wherein said means located above said lamp center includes a toroidal ring connected to said cavity.

9. The apparatus of claim 7, wherein said means located above said center of said lamp comprises a restriction for narrowing a width of said cavity.

10. The apparatus of claim 7, wherein said means located above said lamp center includes an iris in said cavity.

* * * * *

US005811936A

# United States Patent [19]
Turner et al.

[11] Patent Number: 5,811,936

[45] Date of Patent: Sep. 22, 1998

[54] ONE PIECE MICROWAVE CONTAINER SCREENS FOR ELECTRODELESS LAMPS

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[21] Appl. No.: **592,474**

[22] Filed: **Jan. 26, 1996**

[51] **Int. Cl.**$^{6}$ .................... **H01J 65/04**

[52] **U.S. Cl.** .................... **315/39**; 315/248

[58] **Field of Search** .................... 315/39, 298, 267, 315/344; 313/113; 362/341, 343, 396

[56] **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 4,673,846 | 6/1987 | Yoshizawa et al. | 315/248 |
| 4,695,694 | 9/1987 | Hill et al. | 315/39 X |
| 4,954,755 | 9/1990 | Lynch et al. | 315/248 |
| 5,227,698 | 7/1993 | Simpson et al. | 315/248 |
| 5,334,913 | 8/1994 | Ury et al. | 315/248 |
| 5,404,076 | 4/1995 | Dolan et al. | 313/572 |

FOREIGN PATENT DOCUMENTS

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|---|---|---|
| 0153745 | 5/1991 | European Pat. Off. . |

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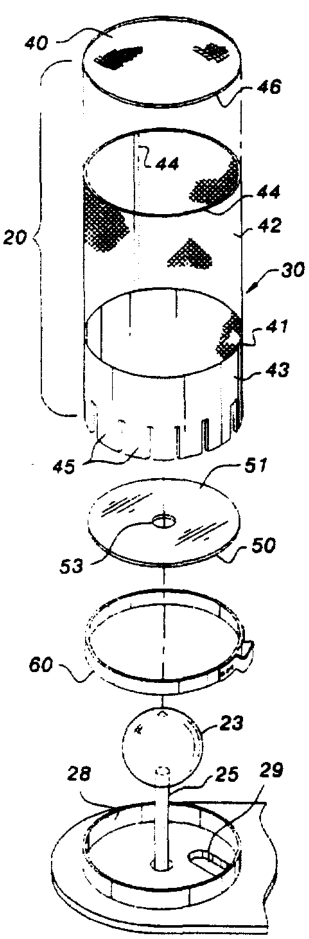
[57] **ABSTRACT**

A microwave powered electrodeless lamp includes an improved screen unit having mesh and solid sections with an internal reflector to reflect light into a light-transmitting chamber defined in the lamp microwave cavity by the reflector and the mesh section. A discharge envelope of a bulb is disposed in the light-transmitting chamber. Light emitted from the envelope is prevented by the reflector from entering the cavity portion bounded by the solid section of the screen. Replacing mesh material by solid metal material as part of the screen unit significantly reduces leakage of microwave energy from the lamp. The solid section has multiple compliant fingers defined therein for engaging the periphery of a flange on the waveguide unit so that a hose clamp can easily secure the screen to the assembly. Screen units of this type having different mesh section configurations can be interchanged in the lamp assembly to produce different respective illumination patterns.

**20 Claims, 5 Drawing Sheets**



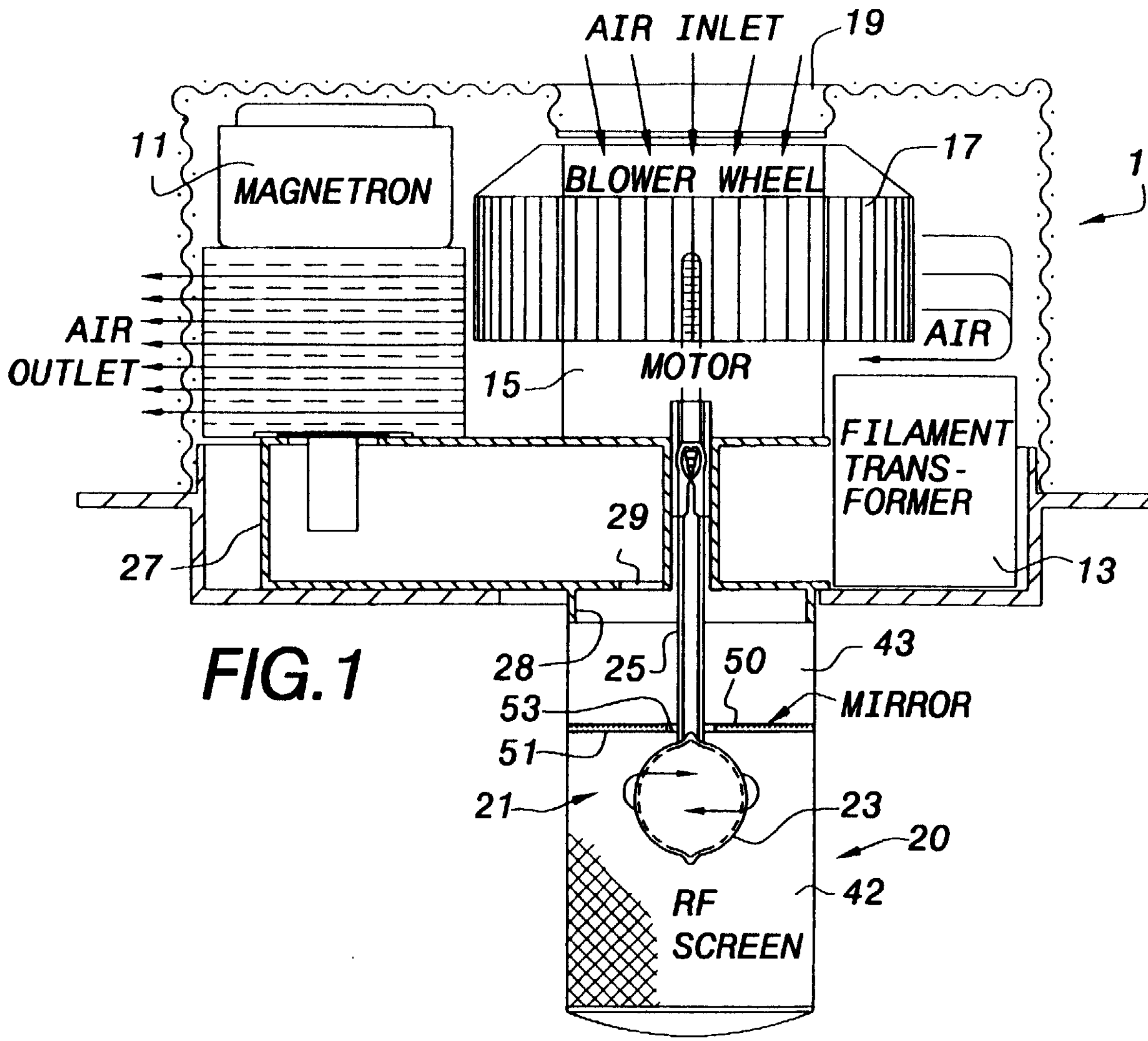
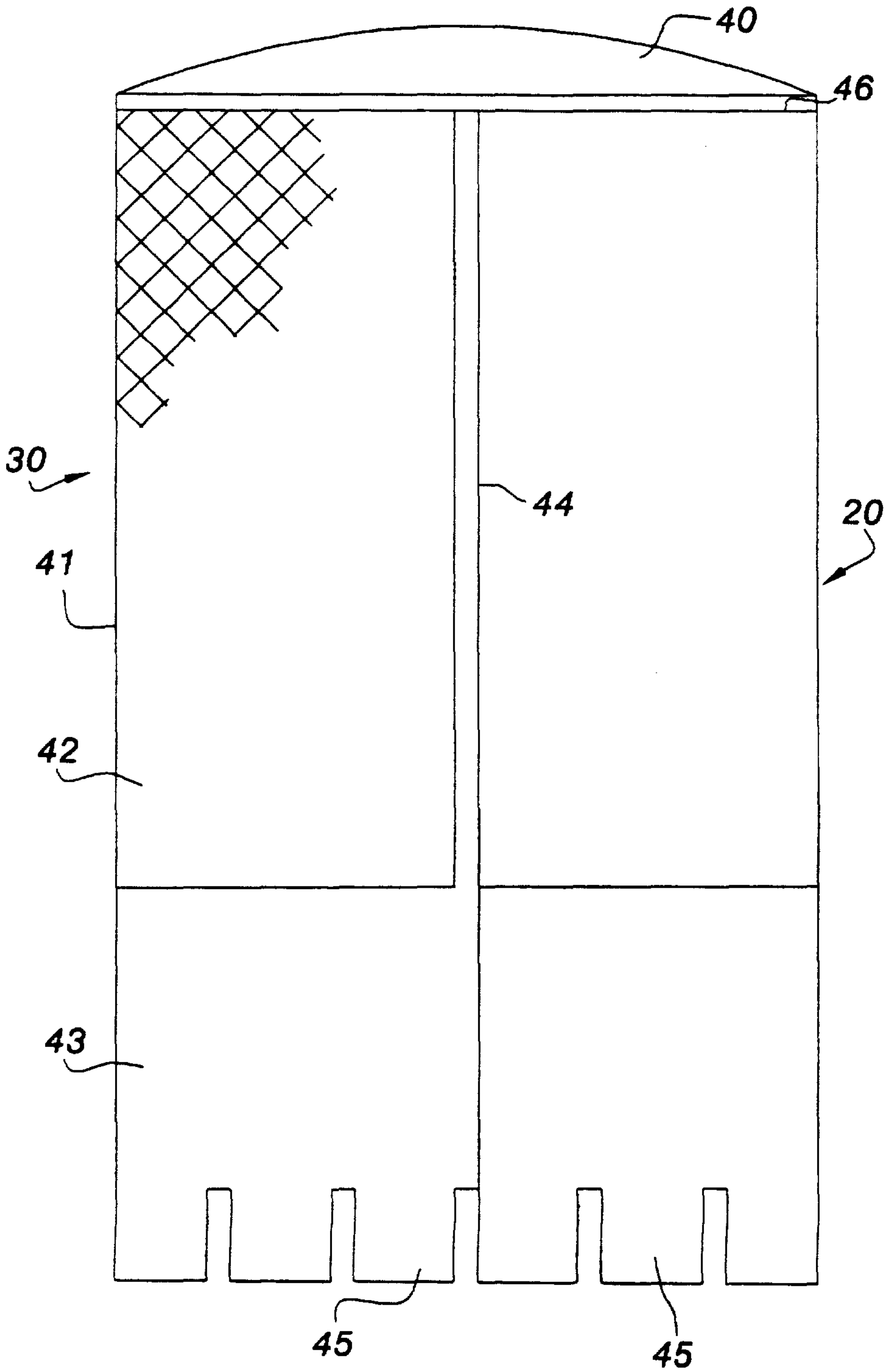

AIR INLET
19
11
MAGNETRON
BLOWER WHEEL
17
10
AIR
OUTLET
AIR
15
MOTOR
FILAMENT
TRANS-
FORMER
29
27
13
28
25
50
43
53
MIRROR
51
21
23
20
42
RF
SCREEN

FIG. 1

FIG.2



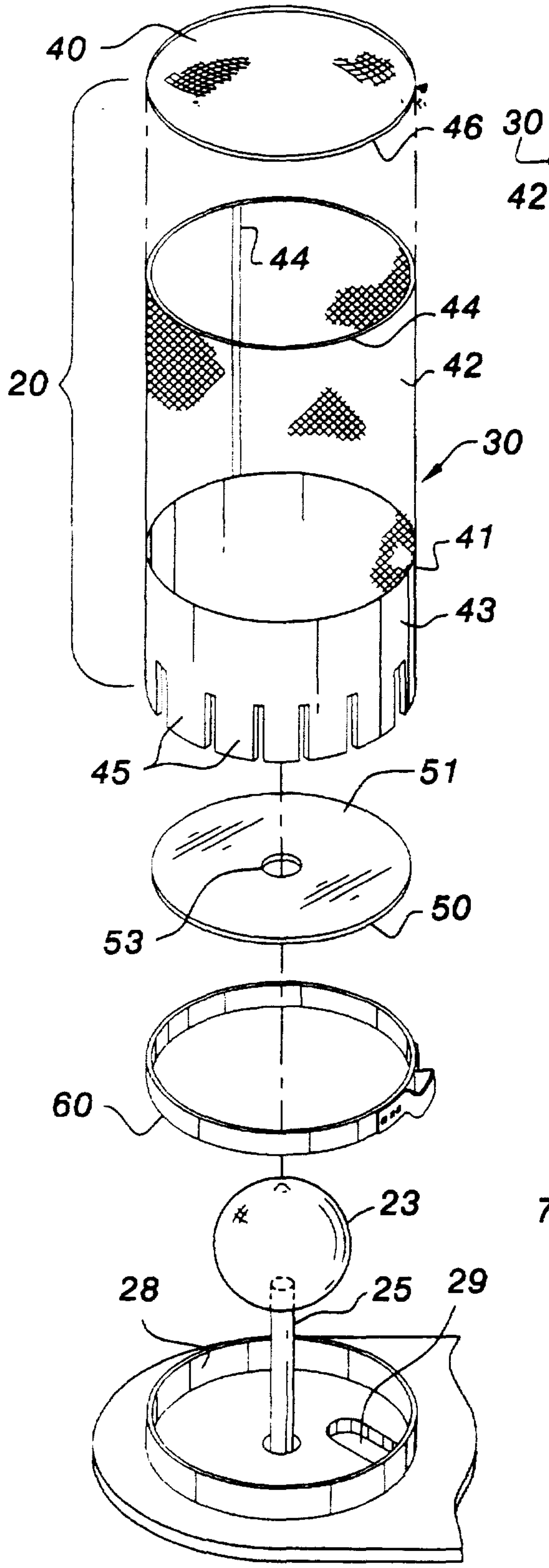



FIG.3

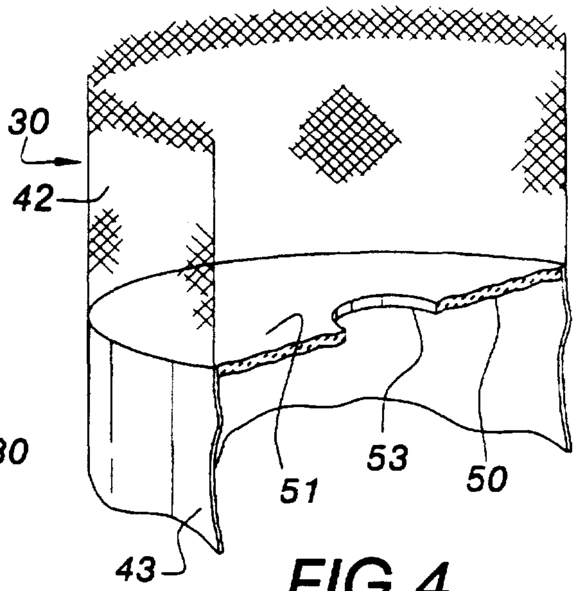



FIG.4

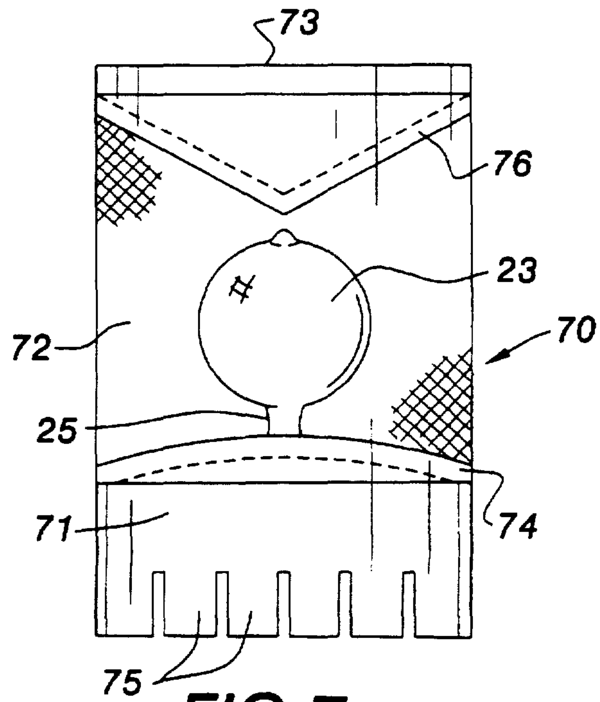



FIG.7

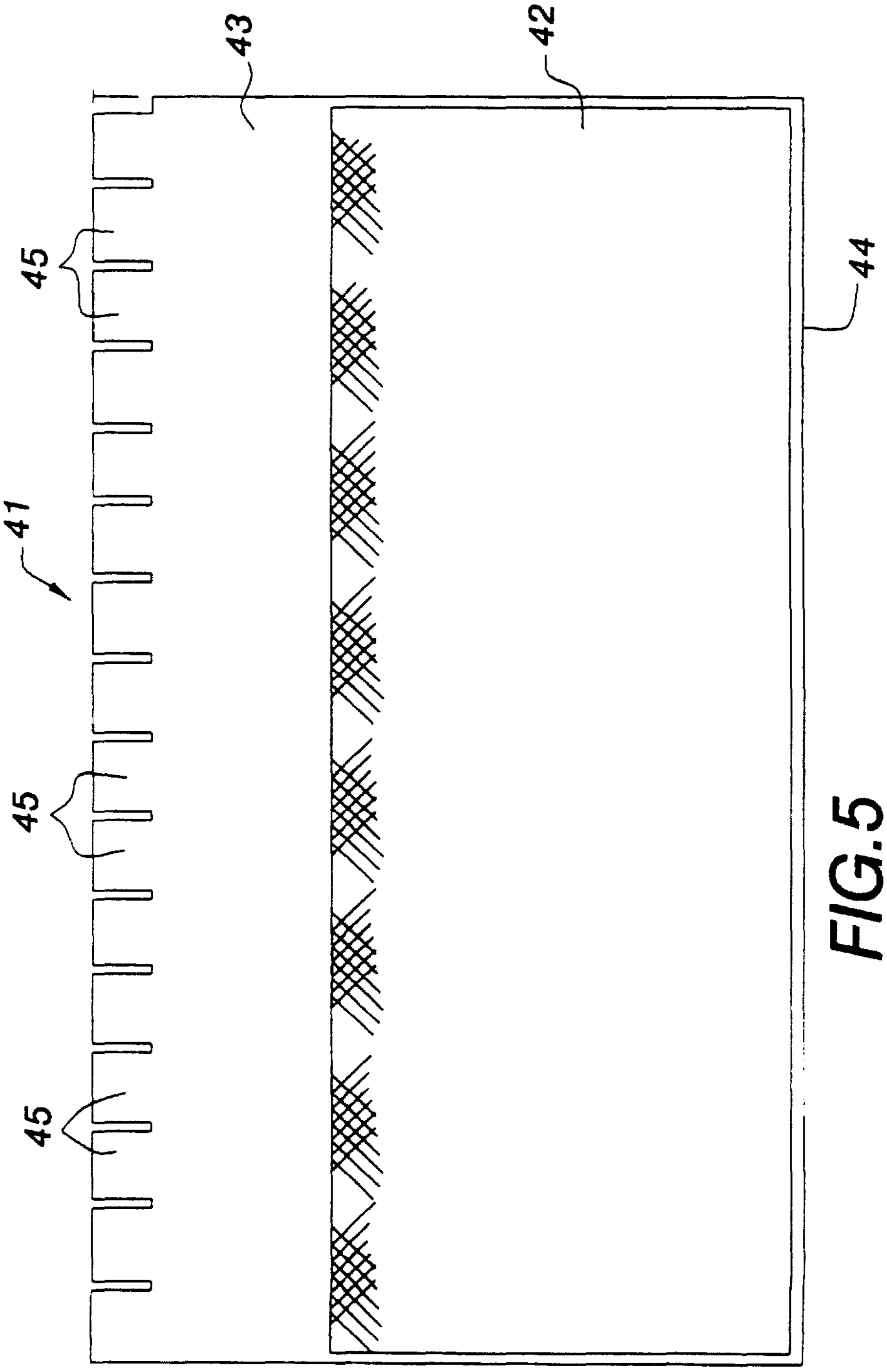



FIG.5

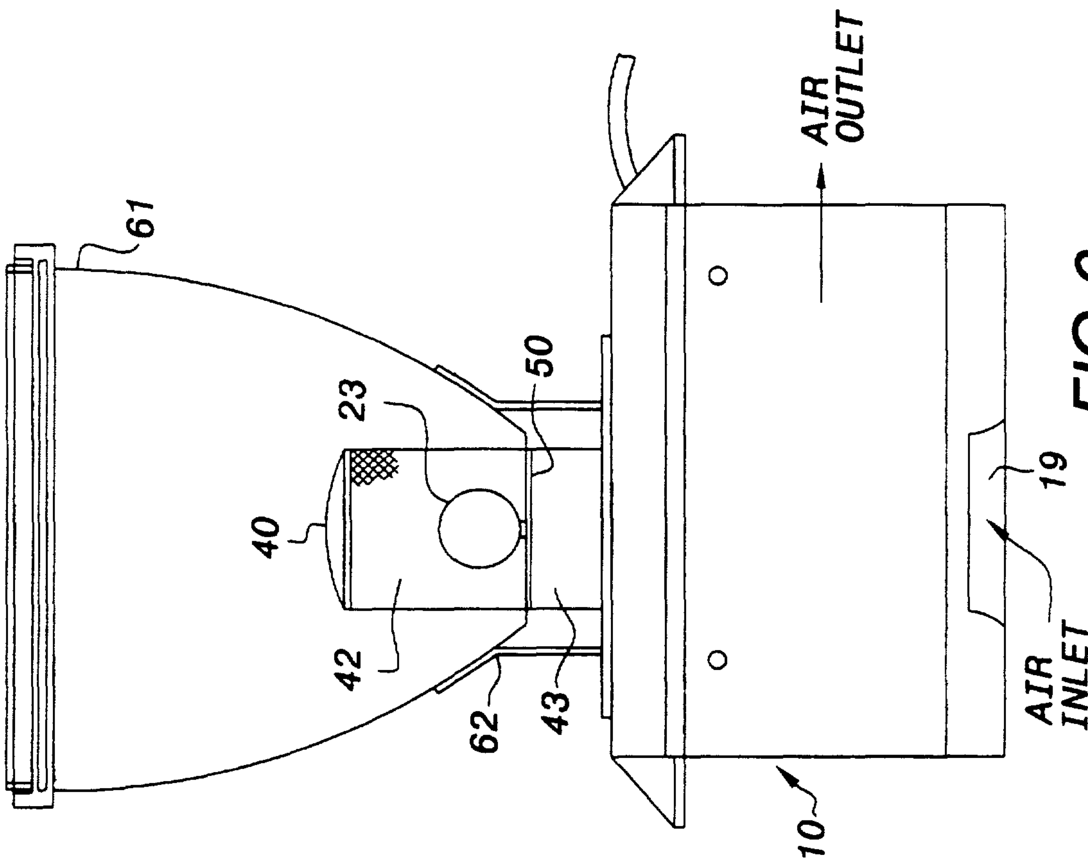



FIG.6

# ONE PIECE MICROWAVE CONTAINER SCREENS FOR ELECTRODELESS LAMPS

## BACKGROUND OF THE INVENTION

1. Technical Field

The present invention pertains generally to microwave powered electrodeless lamps and, more specifically, to improvements in screen structures used in such lamps to block escape of microwave energy while permitting transmission of light.

2. Discussion of the Prior Art

Lamps utilizing radio frequency (RF) energy to excite electrodeless bulbs are well known. Examples of such lamps may be found in U.S. Pat. Nos. 4,954,755 (Lynch et al), 5,227,698 (Simpson et al), 5,334,913 (Ury et al) and 5,404,076 (Dolan et al). The disclosures in all of these patents are expressly incorporated by reference herein. In lamps of this type microwave energy is coupled from a magnetron or other RF source to the lamp bulb via a coupling circuit including a waveguide and a quasi-resonant cavity typically defined, at least in part, by a screen unit. The waveguide functions as an impedance matching device from the source to the cavity.

Prior art screen structures used in microwave powered lamps are disclosed in numerous prior patents as represented by the above-mentioned Lynch et al, Simpson et al, Ury et al and Dolan et al patents, and in European Patent Specification 0 153 745 (Yoshizawa et al). Such screens typically surround a bulb envelope and serve to allow optical radiation from the bulb to escape while forming a conductive enclosure blocking escape of RF energy. Screen design has generally involved an inherent compromise between these factors. Specifically, screens having very low optical loss tend to permit escape of undesirably large amounts of RF radiation. On the other hand, elimination of RF radiation generally incurs the penalty of diminishing optical transmission through the screen.

In addition, in many prior art screens, a metallic ring is attached to the screen base so that the ring can be fastened to the waveguide. The inclusion of the ring as part of the screen adds significant expense to screen fabrication.

Further, in producing a lamp product line, it is often desirable to minimize the cost involved in permitting different optical configurations for different models of lamps. In other words, a manufacturer would prefer to utilize as many common components as possible from model to model. Where components must be changed, ideally they are inexpensive components. It is advantageous, therefore, to provide a screen design that is inexpensive and configured so that the expensive components of a lamp assembly can remain common to various lamp models having different optical characteristics.

## OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an inexpensive screen enclosure for microwave powered electrodeless lamps wherein optical transmission and radio frequency blockage are optimized.

It is another object of the present invention to provide a screen enclosure for a microwave powered lamp that is inexpensive to fabricate yet easily and inexpensively secured to a waveguide.

In accordance with the present invention, a screen structure for a microwave powered electrodeless lamp includes a



metal mesh section and a solid metal section. The mesh section is transmissive to light and non-transmissive to microwave energy at the operating frequency. The solid section is non-transmissive to both light and the microwave energy. In this regard, the term "solid" as used herein is intended to distinguish from the mesh section and connotes the absence of gaps or breaks in the structure.

In the preferred embodiment the mesh section has a right cylindrical configuration with a mesh end cap at one end thereof, and the solid section is configured as a right cylindrical section of like diameter extending coaxially from the opposite end of the mesh section. A reflector, in the form of an electrically non-conductive circular disk, has its annular edge secured at the annular juncture between the mesh and the solid sections, and is disposed coaxially with both the mesh section and the solid section with the reflector's reflective surface facing into the mesh section. The reflector thus defines an optically isolated light transmission chamber within the microwave cavity. An electrodeless bulb has its discharge envelope disposed within the light transmitting cavity surrounded by the mesh section. The reflector is centrally apertured to permit passage of the bulb stem through the space bounded by the solid section of the screen unit.

In its preferred form the screen unit is fabricated from two members. A first member comprises a single thin rectangular sheet of metal, preferably stainless steel, that is etched or otherwise formed to provide the mesh and solid sections therein. The mesh section is bounded along its exterior edges by a narrow solid border, formed as a continuance of the solid section, to facilitate assembly. The second member is a circular metal mesh piece circumferentially bounded by a narrow solid border. In assembling the two pieces to form the screen unit, the rectangular sheet is first rolled into a right circular cylinder such that opposite edges of the sheet are joined. These edges, including the solid border portions of the mesh section, are sealed together by suitable adhesive, welding, or other bonding technique. The second member is then secured as an end cap to the mesh section of the cylinder by adhering together the solid borders at abutting edges of the two members.

The rectangular sheet comprising the first member preferably has a plurality of spaced slots defined inwardly from the edge of the sheet opposite the mesh section. These slots define "fingers" therebetween, the fingers being sufficiently compliant to allow for a small deformation of the edge of the screen unit that attaches to the waveguide. Specifically, these fingers are defined along the annular proximal edge of the screen unit that attaches to the waveguide. An annular clamp, similar to a hose clamp, is used to secure the fingers in place about the waveguide opening.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of specific embodiments thereof, particularly when taken in conjunction with the accompanying drawings wherein like reference numerals in the various figures are utilized to designate like components.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially diagrammatic view in longitudinal section of a lamp assembly employing a screen unit according to the principles of the present invention.

FIG. 2 is a side view in elevation of the screen unit used in the assembly of FIG. 1.

FIG. 3 is an exploded view in perspective of a portion of the screen unit of FIG. 1 showing the manner in which it attaches to the lamp assembly.

FIG. 4 is a broken detailed view in perspective of a portion of the screen assembly of FIG. 3 showing a reflector secured in the screen assembly.

FIG. 5 is a top view in plan of an etched metal sheet used to form the screen assembly of FIG. 2.

FIG. 6 is a side view in elevation of the lamp assembly of FIG. 1 shown with a reflector module attached thereto.

FIG. 7 is a side view in elevation of an alternative configuration of the screen assembly of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring specifically to FIG. **1**, a lamp assembly using the screen unit of the present invention includes a lamp module **10** comprising a housing for a magnetron **11** or other microwave source, a filament transformer **13** supplying filament current to the magnetron **11**, and a motor **15** for rotating a bulb and for driving a cooling fan in the form of blower wheel **17**. An air inlet **19** for fan blower wheel **17** is defined in one end of the housing, and blower wheel **17** causes air to flow through the lamp module **10** to an air outlet, as shown in FIG. **1**.

A screen assembly **20** defines a microwave cavity wherein a bulb **21** is disposed. Bulb **21** includes a generally spherical discharge envelope **23** supported at the end of an elongate cylindrical stem **25**. Stem **25** is secured to a drive shaft of a motor **15** to permit the bulb **21** to be rotated about the longitudinal axis of its stem **25**. Bulb **21** has a fill material contained in its discharge envelope **23** such as, for example, the material described in the above-referenced Dolan et al patent. The bulb is made of quartz or other suitable material.

Microwave energy generated by magnetron **11** is fed by a waveguide **27** to a coupling slot **29** providing ingress to the microwave cavity defined by screen unit **20**.

The screen unit **20** of the preferred embodiment is made from two members, namely a right cylindrical member **30** and an end cap **40** (see FIG. **2**). Each of these two members is formed as a respective one-piece unit. Specifically, cylindrical member **30** is formed from a single sheet **41** (see FIG. **5**) of metal that has been etched to provide a metal mesh section **42** and a metal solid section **43**. Preferably, sheet **41** is a stainless steel sheet having a thickness between 0.003 and 0.005 inches. Mesh section **42** is etched through the sheet, the etching pattern preferably being controlled by computer so that virtually any location of the mesh section or sections and any pattern and size of the interstices of the mesh can be provided. The size and pattern of the interstices are selected to minimize transmission of RF energy through the conductive mesh. As shown in FIG. **5**, in the preferred embodiment mesh section **42** (also denoted by "RFSCREEN" in FIG. 1) and solid section **43** are formed in sheet **41** as adjacent rectangular sections meeting at a straight line juncture corresponding to the abutting inboard edges of these two sections. The three outer edges of mesh section **42** are bounded by a very narrow solid metal border or strip **44** formed as a continuance of solid metal section **43**. The longer outer edge of solid section **43** has multiple slots etched therethrough and extending perpendicular to that edge toward mesh section **42**. These slots define multiple finger-like members **45** which, because of the thinness of the material of sheet **41** and the spacing of the slots, are individually compliant to facilitate attachment of the screen unit to the assembly in the manner described below.

As seen in FIGS. 2 and 3, during assembly sheet **41** is rolled into a right circular cylinder such that mesh and solid



sections **42** and **43** form respective adjacent cylindrical sections for the resulting screen unit **20**. In order to maintain the final cylindrical form of the rolled sheet, opposite edges of the sheet are slightly overlapped, i.e., by the width of border **44**, and then secured together by any suitable means such as adhesive, welding, etc. In the resulting cylinder **30**, the end comprising fingers **45** defined in solid section **43** is referred to herein as the proximal end of the cylinder; the opposite end, bounded by the annular portion of border **44** of mesh section **42**, is referred to herein as the distal end.

In an exemplary embodiment of the present invention, a stainless steel sheet **41** is rectangular in shape and has a thickness of 0.102 mm. The length and width of the sheet are 237.13 mm and 125.73 mm respectively. The width of solid section **43** is 41.91 mm, and the width of mesh section **42** is 83.82 mm. Edge border **44** is 1.52 mm wide. Fingers **45** are sixteen in number, extend 10.0 mm into solid section **43** from the edge of sheet **41**, are separated by 1.3 mm wide slots and are 13.4 mm wide. It is to be understood that these dimensions are provided by way of example only and are not in any way limiting on the scope of the invention.

As shown in FIG. 3, end member **40** is a substantially circular mesh member formed from the same material and by the same process as cylindrical member **30**. The mesh end member **40** is circumferentially bounded by a solid border **46**. Border **46** and the annular portion of border **44** of cylinder **30** are joined together by crimping, welding or other suitable technique to provide a mesh closure at the distal end of the cylinder.

As best illustrated in FIGS. **3** and **4**, a reflector **50** takes the form of a circular disk having an outside diameter substantially equal to the inside diameter of cylindrical member **30**. Reflector **50** is typically made from fused silica and has at least one surface **51** with an optically reflective metal oxide coating which does not absorb microwave energy. A small centrally located aperture **53** is defined in disk **50** and is of sufficient size to permit stem **25** of the bulb **21** to pass therethrough (as shown in FIG. **3**). Reflector **50** is positioned coaxially within the microwave cavity at a location corresponding to the annular juncture of mesh section **42** and solid section **43**. In this manner reflector **50** effectively defines an optically isolated light transmission chamber by optically closing off the proximal end of mesh section **42** from the remainder of the microwave cavity without affecting the quasi-resonant characteristics of the overall cavity at the operating microwave frequency. Attachment of reflector **50** to the cylinder is achieved by placing high temperature ceramic cement (e.g., Saurereisin™ bond cement) at plural locations around the edges of the disk where it contacts screen unit **20**.

The screen unit is secured to the lamp assembly **10** (see FIGS. **1** and **3**) by disposing fingers **45** circumferentially about an annular flange **28** extending from the assembly housing. The compliance inherent in the finger structure facilitates this placement. An annular hose clamp **60** (FIG. **3**) may then be placed circumferentially about the fingers and then tightened by radial contraction to secure the fingers to the flange **28**. Coupling slot **29** from the waveguide is located radially inward of flange **28** so that the microwave energy from magnetron **11** can be delivered into the microwave cavity defined by screen unit **20** as seen in FIG. **1**.

As best seen in FIG. 1, in the assembled unit the bulb discharge envelope **23** is disposed in the optically isolated optical transmission chamber of the microwave cavity defined circumferentially by cylindrical mesh section **42** and at its ends by reflector **50** and end cap **40**. Bulb stem **25**